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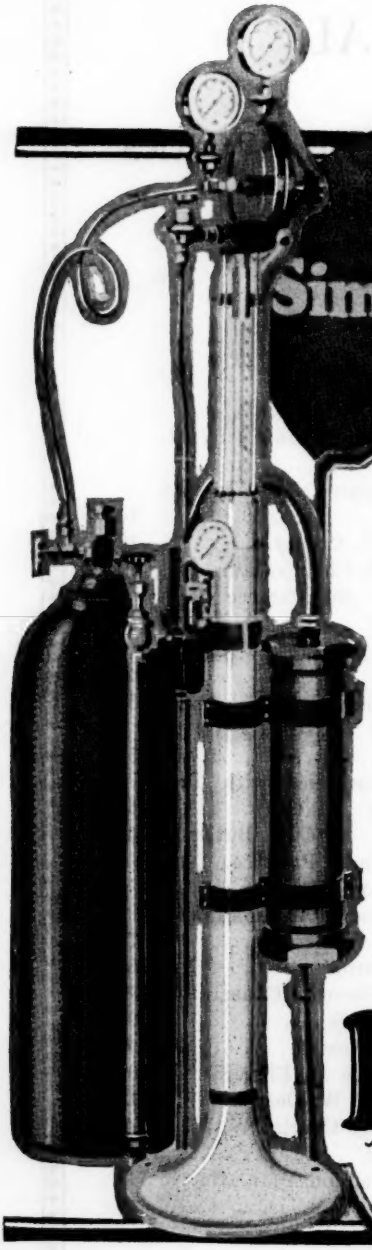

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OPERATING COMBINED WATER AND POWER PLANTS[1]

BY M. SWARTZ[2]

The demand for water is growing even faster than the increase in population of the country would indicate, because a steadily increasing proportion of the population is living in communities served by water works, and with more industries mounting continuously.

This increase in water consumers is accompanied by developments in the territory about each community, which in most cases make it necessary to modernize older water supplies and to build costly new works for additional supplies.

The same conditions hold true in the electrical field. The demand for electric current in the home is growing in leaps and bounds. Electricity is fast becoming our greatest servant. Can you think of a greater calamity or disaster that could happen to our state than to shut down all power plant for a period of sixty hours?

Electric power is remaking the world in every phase of our common life. Its revolutionizing and uplifting force is being felt, in the home, in the mill, mine, factory and agriculture. Everywhere electricity is working a veritable revolution in the modern life. In modern living conditions, electricity is almost as essential as water.

A municipal light and power plant is a revenue project. It is not like the paving of streets, building of sewers, or schools and many

[1] Presented before the North Carolina Section meeting, November 7, 1927.
[2] Superintendent, Water Department, Greenville, N. C.

other public improvements and institutions which are always calling for money from the tax payers, never producing any revenue, and therefore, never paying for themselves, nor earning a profit. A municipal light and power plant is a money maker.

A large number of towns in the state have built electric power plants of their own, and have developed an abundance, and even surplus amount of electric power for their respective communities. The towns are selling electric current for domestic and manufacturing purposes at a price that compares favorably in this section with the lowest prices paid for like service in the Eastern part of our country. These plants have been built by the people and operated by them for their own benefit for many years, at a direct loss without attracting attention of the outside world. They are now operating at a very substantial profit. It is remembered that these plants at first shut down every night at eleven or twelve o'clock. They ran what was known as the "Moon Schedule." This was to economize in operating expenses. Such efforts to economize are well in the past. The plants are now operating twenty-four hours per day, and are realizing a splendid net profit from the business developed.

It is not advisable for every town to operate an electric power plant. The smaller towns should build transmission lines to the city limits of the larger towns, and purchase current at wholesale, and retail it to its citizens. As an example, I will use the town of Greenville, as I know more about Greenville than any other. Greenville is operating a generating power plant, and is serving the following towns: Winterville, Bethel, Robersonville, Parmele, Stokes and Simpson. Ayden will be connected to the Greenville plant in the next ten days. Falkland is under consideration and will be connected to the system by the first of the year. A 22,000 volt, 1000 kw. capacity transmission line, built on Juniper Poles, will not cost over $1000 per mile, and is a desirable voltage for any distance up to 30 miles. By increasing the size of the copper conductor the capacity of this line can be increased to whatever capacity is desired.

Three of the towns served by the Greenville plant operate and maintain water and sewer systems. Robersonville, for example, pays Greenville approximately $600.00 per month for all electric current used by its citizens for light and power; lights its streets and pumps its water. Robersonville collects approximately $1500.00 per month for electric current sold to its citizens. That is, this town buys $600.00 worth of current and sells it for $1500. The net profits

from the Electric Department operate and maintain the water and sewer department; pay interest on a $25,000.00 bond issue and retire these bonds as they come due. The initial cost of the electric department in building the transmission line, substation and remodeling the distribution system was $25,000.00. It would cost approximately $100,000.00 to build a steam generating plant of the same capacity as that of the transmission line. The monthly payroll required to operate a small plant like this will almost pay the total bill for current, purchased wholesale from the neighboring larger plant. It is not wise, for this reason, for the town under 4000 population to operate a generating power plant, but it should build a transmission line to the generating power plant of a larger town near by, say a distance of not over 35 miles. Regarding towns over 4000 population, I will again use Greenville as an example, taking some items from the auditor's report for the year ending June 30, 1927, shown below.

Service sales, electric dept.	$141,087.56
Total expense, electric dept.	67,514.33
Excess of revenue over expenses.	$73,573.23
Service sales, water dept.	$36,033.36
Total expense, water dept.	32,160.91
Excess of revenue over expense.	$3,872.45

The water department was not charged anything for electric current used for lighting its buildings and premises and pumping water. If this charge had been made against the water department the auditor's report would show a loss instead of a small profit.

The water and light department has relieved the tax payer entirely of the sewer, water and electric systems. It makes all water main extensions, installs new fire hydrants; makes all improvements to the water plant and operates and maintains the water plant and system. It makes all new sewer extensions and operates and maintains the sewer system. It makes all line extensions and improvements to the electric plant and operates and maintains the electric plant and system. It pays interest on all outstanding bonds against the sewer, water and light systems, and retires these bonds as they come due. All of the above items are paid out of the revenue of the electric department. The electrical department has not had a bond issue since 1914.

The above report does not only apply to Greenville, but you will find similar conditions in Wilson, Farmville, Rocky Mount, Tarboro, Washington, Kinston, New Bern and other towns which own and operate a combined water and power plant.

The question may arise as to rates. Are we making the tax payers pay for this convenience by paying an excess rate for their electric current? I do not believe you will think so after comparing the following schedule with others.

Lighting schedule:		
Minimum rate	$1.00	
First 50 kw. hrs.	0.10	per kw. hr.
Next 25 kw. hrs.	0.08	per kw. hr.
Next 25 kw. hrs.	0.06	per kw. hr.
Balance kw. hrs.	0.05	per kw. hr.
Cooking and heating schedule:		
First 500 kw. hrs.	0.03	per kw. hr.
Next 2,500 kw. hrs.	0.02½	per kw. hr.
Balance kw. hrs.	0.02	per kw. hr.

The power schedule for large industries goes as low as 1.5 cents per kilowatt hour including demand charges. I believe you will find that these schedules compare favorably with others in the state.

DISCUSSION

MR. J. O. CRAIG:[3] There is just one thing that I would like to discuss along that line.

He has a big surplus from his light plant and a small surplus from his water plant. Unfortunately, a lot of us do not have light plants connected with us. That creates a situation where others of us have to meet similar rates and yet have to provide a surplus from the water department plants to take care of all our operating expenses.

Where there are two plants combined, they ought to make the surplus somewhere proportionate with the electric light plant.

MR. J. E. GIBSON:[4] I had not expected to take part in this discussion, because maybe I am Bolshevik on the matter of combination, and I did not want to throw any sand in the gears.

Some three years ago, Spartanburg had to develop a new water supply, and after looking over the situation finally they went to the

[3] Superintendent, Water Works, Salisbury, N. C.

[4] Manager and Engineer, Water Department, Charleston, S. C.

North Pacolet River, and found that they could put in a dam providing a large storage reservoir. With the drainage area and impounded water they obtained an adequate water supply not only for the present needs but future requirements of Spartanburg. They also found that they could generate power themselves, use that power to operate their pumps and pump the water from Pacolet into Spartanburg, and also would have some surplus power at certain times of the year.

So they developed this prospect and made a contract with the South Carolina Gas & Electric Company to sell them this surplus power when they had it, in case of a deficiency in power they would buy from the company.

I understand the thing has worked out very nicely. The contract is a mutual one. The price to the power company is such that the power company can re-sell it at a profit. Their contract with the power company in case of a deficiency works out very nicely.

The plant has been operating about two years, and I guess has gone through one of the most severe periods of droughts we have had anywhere in the past three years which occurred here in the Southeast.

My objection to combining electric light plants and water works is that I believe that the water works plant, by its very nature, should be owned and operated by the people—as a rule. As a rule, water works affect the health of the entire community.

Under our police control, we demand that certain nuisances be dispensed with—an open well, a cistern. The minute you take away from the individual the right to use an open well or a cistern, you must provide him with a means of getting water. That becomes at least a governmental function right away. I will admit that I am in contradiction with the United States Income Department when they say that a water works is not a governmental function, but a proprietory function.

Electric light is not necessarily so. A man does not have to use electric light unless he wants to in his private home. He can use either gas or electric light, or he can even go back to the old tallow candle.

Therefore, one is a mercantile business and the other is really a necessity of life on which all the citizens depend.

I do not think a mercantile business should be mixed up with a water works business. As Mr. Craig says, the revenue from the electric light plant usually is very large, a surplus built up. We are

all human, we like to work for the man who pays us the most money. If we happen to be managing both plants we are more than likely to give our best efforts to the electric light plant to the detriment of the water plant, which is really the more essential in the end.

MR. J. O. MARQUIS:[5] We consider our electric power plant rather as a by-product. Primarily our plant is a water plant, but the possibilities were there for the development of hydro-electric power, and we have taken advantage of them. We disposed of all our our excess power to the power company.

We keep our accounts separate in the power and the water plants. Last year we had a profit of better than $8,000.00 from our power plant. The total profit of our complete plant was something like $29,000.00. Of course, we charge off against the filter plant the amount of power consumed there at the regular power rates. The rates are 1.4 cents for the first 25,000 K.W. The next 25,000 is 1.35—and so on down. All over 100,000, I believe is 1.25 cents.

We charge the same rates in our filtration plant. For the power we sell to the power company we get a rate of 5 mills. Therefore, you see, we do not have to buy power if we can possibly help it. Last year was a very dry year, but nevertheless we made enough power all through the dry season to pump our water with the exception of two days, and that would not have happened but for the fact that out local power plant in the City of Spartanburg had a fire.

This year, so far, we have not bought any power. Our storage right now is very low. Probably within two weeks, unless we get some rain, we will be buying power.

CHAIRMAN RHYNE: With the Gastonia plant, the electric light end has always shown a little profit. With the water, it has been the other way. We just recently revised our rates in the hope that we could get each one on its own footing. We can tell about the results of that a little later on.

MR. J. D. COCHRAN:[6] Our arrangement is very much like the paper that has just been read. We have had the two combined for the last thirty-five years, I suppose since we started up.

The water plant this year has a net revenue of something like

[5] Water Department, Spartanburg, S. C.
[6] Superintendent, Water Works, Statesville, N. C.

$5,000.00. We charge the light department with the current used at the pumping station. The light department has something over $70,000.00 net revenue.

I think it is a great thing to combine them, because it cuts down your overhead expense and it is much better for the citizens than it is to have them separately.

MR. G. F. CATLETT:[7] The previous discussion has brought out the fact that there are two classes of plants, one in which both the water and light are, in themselves, a complete business; and the second, of which Spartanburg is typical and Durham is also another illustration, where the production of electric current, as one of the speakers has termed it, is a by-product of the water plant.

There is a third class, involving the very small town where only by getting light and water is it possible to get either one. The water alone probably would not have been in. The town is too small to finance it, yet by developing both the water and light system they have been able to finance both.

I recall one little town where they sold the power to a big power company. Immediately the operation of their water plant was a problem to them. There was not enough revenue to pay a man to take care of it, and it became one of those water jobs where the man having charge of it was chief of police, superintendent of streets and water superintendent, and the plant was very much neglected.

MR. C. G. LOGAN:[8] I want to know how you can collect from the city for fire hydrants and street lights and get credit for them. I can never do that. I have to furnish everything, two hundred and fifty street lights and all the hydrants, but cannot get any credit for it.

MR. J. L. BULLARD:[9] The city gives us a credit but they do not give us as much credit as they should. They give us credit for the street lighting and also for the service we furnish the school building. We got a credit last year of $17,000.00 In addition to that, by operating the light and water plant combined, we made a profit of $40,000.00.

The plan is working out very nicely. If we operated the water plant alone, we could hardly make expenses.

[7] State Board of Health, Raleigh, N. C.
[8] Superintendent, Water Works, Waynesville, N. C.
[9] Superintendent, Water, Light and Power Plant, Lexington, N. C.

MR. MCKEAN MAFFIT:[10] If I mistake not, at Wilmington last year there was a committee appointed to consider and report on this very question. We had quite a hot argument in the convention last year about the advisability of consolidating the water and light plants. The question was discussed and one particular instance was offered of Kingston, I believe, where the power companies were exerting every effort possible to acquire the Kingston plant. Godfrey, of Newbern, made the point that if it was not advantageous to the power companies to buy these plants and put the cities out of business from an electric light point of view, why were they offering such a large price for the Kingston plant?

The paper just read here shows why they are offering such a large price for those plants. They are making money.

I agree with Mr. Gibson that the operation of a water plant and the operation of an electric light plant are two separate and distinct entities. Primarily, a water works man is going to look after his water works system unless his electric light plant is paying a dividend. As Mr. Gibson says, human nature is going to call for us to pay more attention to that child that is bringing in the greatest revenue.

But as a citizen, I cannot see the advisability of allowing electric light plants, operated by capital, to profit on what is almost as great a necessity as water supply.

It is not as useful and the lack of it is not as detrimental as the lack of water supply. But in practically every home, except in the very poor classes, electricity has come to be a utility that everybody is using. You almost must use it.

The proper thing to do in a smaller town, particularly, as Mr. Catlett has brought out, where you cannot get one unless you get both, is to consolidate or combine, put in the electric light and the water plant. It benefits your citizenship by giving them good water and electric lights, and benefits your financial accounts by getting your revenues. The power plants are going out and digging for them.

The power plants in Wilmington, owned by local capital, were sold to Northern capital. Northern capital came down and rebuilt the plant, scrapped $600,000 worth of machinery, put in new equipment throughout and started extending their lines all over that section of the state They are now going into all of the smaller towns within a radius of 50 or 60 miles and putting in electric light systems. They are making money by it—witness the fact that they have continued

[10] Superintendent of Water and City Engineer, Wilmington, N. C.

to extend their lines. The cities are making some money by generating their own power—witness the fact that they will keep on doing it—and their finances are in a better condition than ever before.

In Greenville—it was illustrated here—there is a plant that is making money. Mr. Craig, of Salisbury, says that they may be making it hard for the plants that have no electric light system to maintain a plant and meet the rates. I just cannot do it in Wilmington—that's all.

MR. GIBSON:[4] Mr. Maffit, of course, made a very good plea. Mr. Catlett also has. I, myself, think it it is a case of having to swallow the electric light plant to get a water supply, I would certainly swallow the electric light plant and try to make it pay.

There is one reason why the electric plant pays over the water plant, and that is that it is a mercantile establishment with a diversity of uses.

I do not know of anything we can do with water except to drink it and use it as a vehicle of transportation to get rid of our wastes.

But electricity you can sell for the sweeper, for the toaster on the breakfast table or the waffle iron on Sunday morning.

The waterworks started long before the electric light, and it started off on the left foot forward instead of the right foot. The rates were based upon—well, I do not know upon what they were based.

I remember they started off there in Rome. They put an orifice in and said, "You pay so much for that orifice." It is a bit like the electric lights were. They used to charge a dollar a month for sixteen candlepower light—burn it all night or all day, it did not make any difference. It was a dollar. That is the way the water bill was.

Of course, the courts said that the water utility owned by the municipality should not be operated at a profit. But when the electric light came along we kind of forgot about this municipal plant being operated just for the use of the public, and put rates on that did make a profit.

If we could put rates on water works and make a profit we might show a surplus.

THE AMARILLO, TEXAS WATER SUPPLY[1]

By Wynkoop Kiersted, Jr.[2]

Amarillo, Texas, is a city of about 50,000 population. The 1920 census credits Amarillo with a population of 15,494 and it was not until about 1925 that the inhabitants greatly exceeded this number. About that time the production of oil and gas in the Borger field, 60 miles northeast of Amarillo, increased with great rapidity over an extended area. Amarillo located at the intersection of three railroads and already the important distributing point in the Texas Panhandle grew rapidly. Fortunately for Amarillo the oil field is far enough from the city to remove the inconveniences of oil boom operations, but close enough for advantageous business transactions.

The present water supply for Amarillo is taken from 37 wells scattered throughout the city. The water of some of the wells is piped to a storage reservoir at the distributing pumping station whence it is repumped into the distributing pipe system against a service pressure of about 45 pounds. The water from the other wells is pumped directly into the distributing system.

These wells, 300 feet or more in depth, require a lift of at least 270 feet to deliver water at the surface of the group. The total lift, including service pressure in the distributing system is 375 to 400 feet. The cost of operating the plant has been unusually high because of the wide distribution of the wells, the high lift and the relatively small yield of water from an individual well of 50 to 75 g.p.m. Fire service has been supplied by pumps in the main pumping station from a fire service storage reservoir.

The original plant was built in 1901 by H. B. Jones, the present city engineer. It has since passed through several private ownerships and was acquired recently by the city. The city is now reinforcing the distribution system and constructing a new water supply works. The studies for a new water supply were commenced in 1922 by H. B. Jones, city engineer and Wynkoop Kiersted, consult-

[1] Presented before the Chicago Convention, June 1, 1927.

[2] With Wynkoop Kiersted, Consulting Engineer, Kansas City, Mo.

ing engineer. They took into consideration both the impounding of surface and the development of well water along a stretch of nearly 20 miles in the Palo Duro Canyon both southeast and southwest of Amarillo. The several sites southeast of the city were rejected because erosion had drained the quaternary sand deposits of water and because of the porous nature of the side slopes and floor of the canyon. Although the final report recommending the development of both well and surface water supplies about 16 miles southwest of Amarillo was made in May, 1923, no start was made on the final plans until 1926.

The development recommended by the engineers and accepted by the city comprises the drilling of 7 wells of at least 500 g.p.m. each, the construction of an earth dam impounding over 1600 million gallons in the Palo Duro Canyon, a well water reservoir and pumping station at the dam, a pipe line 83,000 feet long connecting the water supply works with a storage reservoir and a distributing pumping station with elevated tower and tank in Amarillo. The cost of the complete development in round numbers will be $2,100,000.

The total ground water supply available at the site was estimated at 7,000,000 g.p.d. and the impounded supply from a catchment area of about 400 square miles at 3,000,000 g.p.d. It is thought that seepage from the impounding reservoir will be high at first, but that the loss of water will diminish over a three-year period as the general water table is raised in the locality and as the porous ground near the dam becomes sealed with sediment.

The wells are located from 1,000 to 1500 feet apart, of which two are below the dam and the others are located near the high water line and upon the north and south banks of the impounding reservoir. The present upward slope of the water table on both sides of the Palo Duro Creek will be reversed under the influence of reservoir storage and doubtless will raise the standing level of the water in all the adjoining wells and increase their yield. At present the standing water level is 20 to 40 feet below ground surface.

CONSTRUCTION OF WELLS

The wells were drilled into the fine sand to an average depth of about 200 feet using a 30-star drilling machine weighing 52,000 pounds. The use of this heavy machine was necessary in handling the heavy casing used in the well. A 6 inch pilot hole was first put down to the clay stratum to develop the geological and water-bearing

structures as a guide to the major operations. A 30 inch hole was then sunk about 80 feet to the water-bearing sand. Inside of and concentric with the 30 inch casing was set a line of 20 inch oil well casing weighing 95 pounds per foot. The 20 inch casing was bailed down to the clay substratum at a depth of 150 to 180 feet below the ground surface. A 15½ inch hole was next drilled into the clay of sufficient depth for submergence of air lift pumps. The permanent well casing is 12½ inches in diameter and weighs 50 pounds per foot. In this line of permanent casing was inserted the strainer section so located as to reach to the bottom of the water-bearing sand. The perforations in the pipe are slots ⅝ inch wide by 4 inches long. About 500 such slots were burned in the 20 foot section of casing forming the strainer. An air pump was next inserted in the 12½ inch casing having an 8 inch eduction pipe extending 196 feet below the ground surface. The next step in the development of the well was to drop a few cubic feet of gravel into the space between the 12½ inch and the 20 inch casing and to connect the air pump with two of three compressors actuated by gas and steam power.

The setting now being complete for the development of the well, the 20 inch casing was pulled slowly, a few inches at a time, and water pumped by air lift from the well. As water was pumped sand flowed freely under the 20 inch casing and thence out of the well and the gravel between the outer and inner casing settled. Pumping continued moderately until the water cleared. The clearing of the water indicated that the cavity formed by the removal of sand had filled with gravel and that the velocity of water at the surface bounding the deposited gravel was so low that the sand would not carry through the voids. With clear water flowing the 20 inch casing was raised a few more inches, thus increasing the velocity of water and again a heavy flow of sand occurred. In order to keep the sand and gravel thoroughly agitated and the gravel forced back into the cavity made by the developing process the well was alternately pumped and "back blown." To back blow the well the discharge valve was closed. The escape for air through the eduction pipe being thus shut off the air after forcing water out of the eduction pipe into the ground, passed through the strainer opening and bubbled up through the gravel causing it to "boil." The back blowing action also kept the gravel from arching in the casing and the "boiling" or rising and falling of the gravel had the effect of forcing the gravel away from the well strainer. The valve upon the discharge pipe was opened after each

two to fifteen minute period of back blowing. The pressure in the well, thus suddenly reduced to nearly zero from a pressure equal to the full head of water in the ground, caused an inrush of water at high velocity and a heavy flow of sand with it. The well was again pumped after back blowing until the water cleared.

The process of pumping, "back blowing," raising the 20 inch casing and feeding gravel enough to keep the upper gravel surface a few feet above the end of the 20 inch casing was continued intermittently until this casing had been entirely withdrawn. The space between the 12½ inch casing and the wall of the 30 inch hole was then filled with gravel to the ground surface. Alternate pumping and back blowing was continued until the inflow of sand became small.

At least 100 cubic yards of gravel were used around the strainer pipe of each well, more gravel being deposited at the bottom of the wells and around the strainers than at the top of the sand strata. A test hole put down 6 feet from the center of several wells encountered the deposited gravel in each case but additional test holes were not drilled to define the shape of the gravel cone. From the uniform texture and size of the sand it is believed that the distribution of gravel around the strainer is uniform and somewhat conical in shape. About 35 working days are required to make a well by the above described process at a cost of $14,400.00 each.

The usual feature about this work is that from 500 to 800 gallons of water per minute are developed from a single well sunk in sand too fine to furnish such a flow of water from wells constructed by the usual methods. Many mechanical analyses of the sands from these wells were made, which for several of the wells, but typical of all, average 40 to 52 per cent retained on a No. 60 sieve and from 60 to 68 per cent retained on a No. 80 sieve. The large yield of water from this grade of sand is due to the extended distribution of graded gravel through the use of compressed air.

SAND TRAPS

A continual run of sand in small amounts is expected of the wells in operation. In order to meet this situation each well head consists of a reservoir forming a sand trap. These well heads are designed of reinforced concrete of sufficient capacity to allow the sand to settle out as water is being pumped. Provision is made for the removal of sand from the traps by flushing. In order to prevent the graveled well strainers from becoming sealed with the fine sand, provision is

made for back blowing the wells through properly valved connections, disposing of the sand ladened water after back blowing through a waste pipe which by-passes the sand trap; also provision is made for feeding gravel simultaneously with the back blowing and thus to avoid the danger of the well eventually caving. It is thought that the periodical back blowing and gravelling of the wells will progressively improve the conditions for an increasing yield of water which is an expectation quite the reverse of that for the ordinary fine strainer well in fine sand strata.

Besides the sand traps at the respective well heads there is an additional sand trap at the 500,000 gallon covered reservoir receiving the water from all the wells. This receiving reservoir has a weir chamber for measuring the water delivered from the wells.

The air lift method was selected for pumping the wells because of the provision thus afforded for back-blowing combined with the advantage of the absence of moving parts to be cut with sand. All of the wells except the first one drilled (the test well) were sunk to a depth sufficient to provide the requisite submergence for efficient air lift pumping. The first well drilled to a depth of only 146 feet has installed therein a Worthington Axi-flow pump. If the operation of the Axi-flow pump proves unsatisfactory, it is intended to remove the pump, drill the well deep enough to afford submergence for economical air lift operation and to install therein an air lift equipment. However, it is hoped that the cost of maintenance and operation of the pump will prove low enough to insure continuous use. Provision has been made for back-blowing and graveling this well in the same manner as for the air lift wells.

PUMPING AND DISTRIBUTION

Water is pumped from the 500,000 gallon receiving reservoir to Amarillo through a 30 inch lead jointed cast iron pipe line 83,000 feet long. The two pumps for this work are centrifugal pumps each of 4 m.g.d. capacity operated by 150 H.P. synchronous motor. When pumping at a 4 m.g.d. rate it is necessary to pump against a head of about 110 feet or just enough to raise the water over the rim of Palo Duro Canyon at elevation 3715, whence it will flow by gravity to the Amarillo storage reservoir where the water line is at elevation 3672. When pumping at a 10 m.g.d. rate with several pumping units the total lift of the pumps will reach about 160 feet. The present impellers are designed for pumping against the lower head and the plan

is to replace the impellers with ones designed for 160 feet head when the consumption of water in Amarillo warrants the change.

The air compressors located in the same building with the centrifugal pumps above described are two stage compressors operated by 150 H.P. synchronous motors. An over-all operating efficiency of 35 per cent from current consumed to water pumped by the air lift pumps has been guaranteed by the Sullivan Company.

Electric power to operate all of the motors is generated in Amarillo and transmitted by a pole line 21 miles long with step up and step down transformers erected and owned by the Amarillo Light and Power Company. A power rate was obtained by Amarillo of 1.35 cents per kilowatt hour for power on the switchboard.

A gasoline engine driven stand-by generator has been installed for emergency service. The operating cost of such a unit is high, but the demand for its use is almost negligible because of the dependable character of the new generating equipment and pole line installed by the Power Company.

Bids were received upon cast iron, concrete and steel pipe for the pipe line. The contract as it was awarded required the use of cast iron pipe of French manufacture. A comparison of the bid prices follows:

30 inch Matheson Joint Pipe line complete in place...	$1,288,933.51
30 inch Hammerweld Pipe line complete in place.....	1,146,207.91
30 inch Riveted Steel Pipe line complete in place.....	766,159.51
30 inch Lock Joint Pipe line complete in place.....	654,885.30
30 inch Cast Iron Pipe line complete in place.....	609,137.00
27 inch Lock Joint Pipe line complete in place.....	546,894.00

SURGE TANKS

Three concrete surge tanks 6 feet inside diameter are located at three summits along the pipe line while air relief valves have been set at other summits and drains placed in all valleys. The concrete surge tanks have a square footing slab, an octagon pedestal and cylindrical shaft. In constructing the shaft a vertically reinforced concrete shell 6 inches thick was first built and hooped with steel bands drawn up with turb-buckles until the steel was stressed to 14,850 pounds per square inch. The concrete was thus put in initial compression so that when the shaft was filled with water this initial compression would be relieved but without producing tension in the concrete and a tendency to crack. The steel bands were then covered with gunite or a

jacket of concrete for protection. The method of surge tank design used was that patented by Wm. S. Hewitt of Minneapolis, Minnesota.

A fourth surge tank of similar construction is located at the 5 m.g. distributing reservoir in Amarillo. It is provided with a hydraulic valve by-pass and over flow pipes and is designed to prevent water ram and the emptying of the pipe line when pumping ceases at the water supply station. When the hydraulic valve is open water flows through the base of the surge tank into the reservoir; when the valve is closed the water rises in the surge tank flows over the bell mouth of the vertical overflow pipe erected inside the surge tank, thence into the reservoir. The elevation of the rim of the bell mouth is a few feet below the top of the surge tank and nearly at the same elevation as the ground at the supply end of the 30 inch pipe line. Thus the storage in the supply main approximating 2½ million gallons is conserved except for unavoidable pipe line leakage.

Rapid progress was made on the pipe line with an Austin trench machine which cut a 54-inch trench and dug the bottom depressions for bell holes. The rate of progress made by the machine averaged about 1200 feet per day.

Breakage in the cast iron pipe aggregated 350 pieces of the 4 meter pipes. About half of this amount was broken between loading in France and the time it was loaded upon the train at Galveston. The remainder was broken in transit and in distribution on the ground. The cost per ton of 30 inch cast iron pipe f.o.b. Amarillo was $46.00 per ton.

DISTRIBUTING RESERVOIR

Water is delivered from the 30 inch supply line into a stilling well prior to passing over a measuring weir into the inlet chamber of the distributing reservoir. The inlet chamber is so gated that water may pass directly to the pumps or into the reservoir, also so that the inlet chamber can be by-passed and the pumps supplied directly from the reservoir.

The reservoir proper was designed with a flat slab reinforced concrete cover supported upon columns. The total depth of the reservoir is 20 feet, but in order to economize in concrete the side walls are but 12 feet high with a one on two slope extending from the toe of the wall footing to the center line of the outside row of roof columns. The columns are spaced at 19 foot centers. The 4 inch concrete floor was laid in sections 19 feet square upon 12 inches of gumbo

puddle. The same thickness of gumbo and concrete cover the side slopes. The $\frac{3}{4}$ inch joints between adjacent concrete sections of the floor and side slopes are caulked with gumbo puddle driven in on oakum strands.

The inlet chamber walls are monolithic with and form a part of the pump house substructure as will be shown by a slide. The reservoir structure is independent of the pump house substructure. An expansion joint of unusual design is used at the junction of the reservoir side walls and the pump house substructure. Tongue and groove joints are provided at the junction of the reservoir wall with pumping station basement walls so designed as to form a well 9 inches square between the tongues and grooves in the concrete. The well is packed full of gumbo for sealing the joint against leakage. It remains accessible from the top for repacking.

The pumps for pumping water from the reservoir into the distribution system are installed at an elevation 3 feet above the bottom of the reservoir and are therefore always self-priming. Two independent lines of suction pipe connect the reservoir with the suction header inside the pump basement. The 16 inch branch discharge pipes connect each pump with the main discharge header which is also inside the pump basement, and supplied with a venturi meter.

Above the header chamber is an electric room 14 feet by 20 feet wherein all electrical control equipment is installed. The front wall of the electric room is formed by the switchboard which overlooks the pumps and which is operated from a balcony overhanging the pump basement. Adjacent to the electric room and also over the pump header room is the heater room in which an oil fired steam heater is located. This room is 9 feet by 14 feet.

Above the electric room is the office of the engineer and above the heater room is a toilet, shower bath and locker room. Subway gratings have been placed in the floors of the main office, the electric and the pump rooms.

A 500,000 gallon elevated tank is connected with the 24 inch discharge pipe which serves to equalize the pumping rate. One 4 m.g.d. and one 6 m.g.d. pump have been installed and provision is made for the future installation of two pumps which can be of a capacity of 8 or 10 m.g.d. each if desired. The 5 m.g. reservoir can be enlarged at any time there is need for additional storage.

WATER WASTE SURVEYS[1]

By Frank H. Prouty[2]

A water waste survey has an individuality all its own. The purpose of such a survey is to detect and remedy leaks in water mains, breaks in smaller pipes, losses through open or defective valves, leaks in fixtures and connections and industrial wastage. Such a survey also discloses the presence of obstructions in the pipe, the existence of closed valves or the inadequacy of the pipe for the flow demanded.

To begin a water waste survey, a check is first made on the total water supplied and, if meters are already in use, a check is taken to verify their accuracy. If the supply is being measured by theoretical displacement of plunger pumps, slippage due to defective valves, leaky plungers or short stroking may result in an error as high as 50 per cent. If venturi tubes or orifice plate meters are in use, the recording device may be in error, so, regardless of what measuring devices exist, a check is taken on the amount of water supplied.

Having checked the supply, the delivery system is next subdivided into sections and each section is separately surveyed. The sections are so selected that all the supply valves but one may be closed and the section will then draw all its supply through one line. The flow in this line is then measured and particularly is it measured at night. Except in industrial districts running on a twenty-four-hour schedule, the flow from midnight to 4 a.m. should be very light. During the day, an average consumption for the population blocked off indicates the expected flow and if an excessive flow is shown for either night or day, the wastage is run down by progressively blocking off sections within the section until the flow is traced to the point in question.

Some sections will show at once that no improper use of water exists and such a section is immediately eliminated from the survey. The work soon narrows down to the sections of greatest waste and a systematic survey will always disclose the offender. If the finger of

[1] Presented before the Rocky Mountain Section meeting, February 23, 1928.

[2] Consulting Engineer, Prouty Bros. Engineering Company, Denver, Colo.

guilt points to a few blocks of residences, the survey may be completed more quickly by testing each residence with an aquaphone attached at the curb box. This instrument records the sound caused by even a slight flow through a leaky fixture.

Many leaks disclosed by a water waste survey would not be discovered in any other manner, particularly the common case where a broken line drains directly into the sewer without any surface indication of the break.

While making a water waste survey defective valves are often discovered and it is necessary to place these valves in operating condition before completing the survey. While such repairs appear to increase the cost of the survey, the fact that valves are necessarily placed in operating condition is considered one of the points in favor of making the survey.

The most specialized part of making a water waste survey is the operation of the instrument by which the flows are measured. A special form of pitot tube is used, designed to pass through a 1 inch corporation cock. The corporation cock may be installed in the pipe while under pressure and no "shut offs" are necessary. Another outstanding advantage of the pitot tube is that the same tube may be used for pipes ranging from 4 inches to 6 feet in diameter.

The method of making a pitot tube measurement of flow is briefly as follows: A point is selected in the pipe line whose flow is to be measured where there is at least twenty pipe diameters of straight pipe upstream and five diameters of straight pipe down stream. The clamp is applied and a 1 inch corporation cock is tapped into place. A caliper rod is first introduced through the corporation cock and the existing inside diameter of pipe is accurately measured. The measured diameter is divided into rings or annuli of equal areas and the center of gravity of each ring is computed. Then an average of the velocity readings at each center of gravity gives the total velocity average for the entire pipe area. The velocity at the center may be twice the velocity along the wall of the pipe and the velocity in the lower section of the pipe will be greater than in the upper section, so the traverse must be carefully taken if accuracy is desired.

When the traverse average has been carefully established it is compared with the velocity at the center of the pipe and the relation betwen the two is called the traverse coefficient. The pitot tube is then set at the exact center of the pipe and a single reading of the pitot tube times this traverse coefficient will permit a calculation of the flow accurate within 2 per cent.

The least flow which may be read with accuracy is three quarters of a foot per second and the greatest flow permissible is 10 feet per second. The same manometer may be used for the full range in velocities, a working differential being obtained by using displacement liquids of different specific gravity. For weak flows, carbon tetrachloride and benzol are used (1.5 sp. gr.) for medium flows bromoform is used (2.8 sp. gr.) and for high velocities mercury is used (13.6 sp. gr.).

A water waste survey is directed toward the involuntary wastage of water rather than the voluntary. It is not intended as a restraint on the person irrigating so freely that most of the water runs off the lawn and into the sewer or against the person who will temporarily waste water on cold nights to prevent freezing of pipes. Voluntary waste of water is best corrected by installing meters. The permanence of the savings made by a water waste survey is not dependent on the good behavior of the consumer. A water waste survey will cause a decided saving in water even where meters are completely installed and there is no voluntary wastage.

There are several organizations making a specialty of water waste surveys and any one of them will undertake such a survey with a guarantee that the savings effected in one year will exceed their total charges with water valued at 6 cents per one thousand gallons. The cost of making a water waste survey for a city of 10,000 population is about $2,000. Incidental expenses are involved due to the necessity of uncovering mains, repairing valves, attaching corporaton cocks, transporting shelter houses which protect the instruments and, most important of all, immediately repairing the leaks found.

In cities where water is 100 per cent metered, delivery systems are seldom efficient enough to sell 90 per cent of the water accounted for at the intake and the average water works only accounts for a sale of approximately 65 to 70 per cent of the supply.

Where all water is treated and pumped, the financial loss is tremendous and the best method of attack is to make a water waste survey. However, water is not always considered so valuable. In western Colorado with our mountains, our generous water supply and our gravity flow pipe lines, many towns are not seriously concerned with the quantity of water used. In Denver, for instance, a water waste survey has never been made. The Denver system is made up of a consolidation of a number of independently designed systems which when merged have not made an especially efficient whole. Water is

provided in Denver on a flat rate basis and no one is particularly concerned whether a customer uses ten times a reasonable amount of water or gets along on half his share. It would be hard to imagine a city where a water waste survey would be more fruitful in results than in Denver. On the other hand, only one fourth of Denver's water is pumped, the reservoirs contain a surplus, the distribution system is being made sufficient and it becomes questionable whether the enormous quantity of water which could be saved would net any appreciable return to the city at this time. For the same reasons, it must be admitted that at this time the tremendous saving in water obtainable by installing meters would not appreciably reduce operating expenses and would seriously reduce the revenue. In other words, at the present time it is cheaper for Denver to increase the supply than to decrease the consumption, a fortunate condition which will not always obtain and which is shared by but few other cities.

Cities facing a water shortage and the immediate necessity of heavy expenditures for an increased supply, might save enough water through a water waste survey to make the old supply adequate for a number of years to come.

REDUCTION OF POWER COSTS[1]

By C. S. Chamberlain[2]

The average available power in the United States today is about five horsepower per capita. The ordinary Chinese coolie who is supposed to be about the best average worker of the world today develops about one-eighth horse-power. You can readily see therefore, how much available horse-power and how many slaves we have at our command today. When your wife kicks about the amount of work she has to do, tell her she has five horse-power available and that it is equal to forty slaves. Take King Solomon in all his glory! Could he get together enough slaves to take him to Chicago in the time that we could get there now?

In the early days of commercial power generation, there were two kinds of current considered and installed.

In the larger cities in the conjested area, where power was needed and used, they installed mostly low voltage, direct current for light and power. In the cities' outlying districts or in the smaller towns they installed mostly alternating, single phase current of 133 cycles, 1100 volt, "primary."

This higher voltage was used in serving larger sparsely settled areas with electric current for lights, transformed from 1100 volts primary down to 52 volts secondary. No commercial single phase motors of any size were manufactured for use on these lines at this time.

Having only lights on their circuits, they almost had a unity power factor and no one need worry about a low power factor on their generators and lines.

Then came the single phase and the polyphase alternating current motors, which had squirrel cage rotors and wound rotors which operated at a lower power factor. This low power factor used up the capacity of the electric generator lines and transformers with no return to the power producer for these losses. The ordinary cus-

[1] Presented before the Indiana Section meeting, March 16, 1928.

[2] Superintendent, Waterworks, Rensselaer, Ind.

tomer's watt hour meter does not record these losses, consequently the customer with a lower power factor in his motors should be penalized and the customer with a higher power factor should receive credit on his monthly bill.

As a rule the water works pumps adapt themselves to the use of synchronous motors as they are operated almost continously at a good load factor. Quite often they are located at long distances from the source of current supply, thereby correcting considerable power factor on electric generator and lines leading from the electric generator to the synchronous motor, whose lines may be serving many low power factor customers and may need much correction.

SYNCHRONOUS ELECTRIC MOTORS

A synchronous motor is a motor used for correcting a low power factor on an electric generator and power lines. These motors are so constructed that they will correct this factor to a large extent and in the meantime will develop their full rated horse power.

The size of the motor, operating conditions and location of motor as to the source of current supply should determine the savings which can be made for the power producer, if the power customer uses synchronous motors in driving his water works pumps. This power customer should be credited with the savings, and his rate scheduled accordingly.

Often another saving may be made by installing a synchronous motor in connection with other existing squirrel cage, or wound rotor slip ring motors, as they will correct the low power factor on the existing motors, transformers, and lines and will allow the addition of power in plant without overloading.

About the only serious objection to the installation of the modern synchronous motor is the price. There is one patented make that costs about one-third more than the ordinary slip ring induction motors and may be purchased in sizes from 5 h.p. up. Many of the large electric manufacturing companies have made synchronous motors from 50 h.p. up for thirty years. Some of them are now making smaller motors.

The above patented motor will start heavy loads without difficulty. After the motor attains synchronous speed which it will do easily, with a 150 per cent load, it becomes a self-excited synchronous motor. As a synchronous motor it will carry 150 per cent load without falling out of step. Above this value it operates as an induction motor and

continues to run as such to the "breaking point," which is rarely less than 250 per cent of full load torque and usually more.

For those present who have not had an opportunity to study electricity, I will say that "synchronizing and paralleling" are very simple operations. It is about the same as rotating two parallel shafts at the same speed and then connecting them together with a jaw clutch without clashing gears, and rotating all together in step.

ENGINEER FOR ENGINEER'S JOB

When you have an engineering job, either chemical or mechanical insist on the company or municipality furnishing you with a consulting engineer, even though you are capable of handling the job, for these extra responsibilities will eventually ruin your health. I have been passing through a siege of this kind during the last four years.

Three years ago we relocated our water works pumps and installed one 550 B. P. H. Diesel engine, which we use in connection with our old steam plant. Last year we installed a new 14 panel modern switchboard, and we are now installing one of the very latest 875 h. p. Diesel engines with an electric generator which will run in connection with our other Diesel engine, and with some of the old steam plant.

AMERICA'S FIRST ENGINE

The first American Diesel engine was built by Adolphus Busch in St. Louis in 1898 under the patents and drawings of Rudolph Diesel of Germany who invented the Diesel engine.

The first American Diesel engine developed 60 brake h. p. in two cylinders and was installed in the Anheuser Busch brewery. It was the first one to be placed in regular operating condition.

Dr. Diesel's first experiments were conducted with powdered coal as fuel for the Diesel engine of about the same grade now used in many modern steam boiler furnaces. His original idea was to inject powdered coal directly into the engine's cylinders with an air blast and ignite it by the heat of compression in the cylinder. This he was able to do, but the coal left so much residue and it was so difficult to lubricate the cylinders, that he abandoned the idea and took up heavy oil instead in his experiments. In this way the large modern Diesel engine was developed.

THE TRUE DIESEL ENGINE

The true Diesel engine has its oil injected directly into the cylinder by a blast of air ranging in pressure from 600 to 1000 pounds and at 6 or 8 degrees before the piston reaches dead center. The oil is ignited by the heat of compression which must be in the neighborhood of 460 pounds. This makes a temperature of about 1000 degrees Fahrenheit. These heat units are many times higher than necessary to ignite the injection atomized oil.

Thermal efficiencies

The inherent thermal dynamic efficiency of the Diesel based on useful output varies between 32 and 35 per cent. Simple Corliss or four-valve steam engines with the ordinary furnaces and boiler pressures average about 6 per cent thermal efficiency.

Compound Corliss steam engines give about 9 per cent; triple expansion steam engines about 18 per cent and they must have a good load factor to reach this point of economy.

Modern steam plants with higher boiler pressures, superheated steam, economizers, and condensing engines or turbines, show a thermal efficiency of 20 to 22 per cent and must be very well operated to reach and maintain this point.

The average amount of coal required to make a kilowatt hour as shown by the United States Census Bureau for 1927 is 1.8 pounds. This means that a very good steam plant must use in the neighborhood of 24,000 B.t.u. to make a kilowatt hour. One kilowatt hour has 3,412 B.t.u. One mechanical horse power hour has 2,542 B.t.u.

A Diesel oil engine under full load will produce a kilowatt hour with about 0.56 of a pound of fuel oil or 10,080 B.t.u. per kilowatt hour. You can readily see that the B.t.u.'s required by the Diesel is only about one-half of the requirement of the modern steam plant. These however must not be all of the determining features as to the modern type of equipment to use.

Almost all mid-continent 24/26 gravity fuel oil has 18,000 B.t.u.'s per pound. Indiana coal has about 12,000 and Pittsburg coal has from 13,500 to 14,000 B.t.u.'s per pound.

The price at which you can buy these B.t.u.'s delivered and handled in your plant must be the determining factor as to the equipment you should use.

If many of the old plants will check up on their old equipment they

will find that their B.t.u.'s per horse power are many times the figures given above, and that the expense for new and modern equipment will soon be returned by the savings to be made.

DISCUSSION

MR. CHARLES BROSSMAN:[3] It would probably not be out of place to go back into history a few years and ascertain the reason for the present unit of boiler horse power. At the Centennial Exhibition in 1876, it was believed that some necessary unit for a boiler horse power should be determined upon. There was no available information on such matters at that time. Corliss had just been developing his Corliss valve gear and his engine was probably the best example of efficient power.

A committee at that time was conducting a series of boiler tests and in order to arrive at a boiler rating, they considered 30 pounds of steam per horse power an hour as the economy of the best non-condensing engines of that period. They, therefore, used 30 pounds of steam per horse power at the then prevailing pressure of nearly 70 pounds and with an assumed feed water temperature of 100° and called this a boiler horse power.

Considering the conditions at that time, this was no doubt a logical and reasonable figure and was so accepted by boiler manufacturers.

Ten square feet of heating surface in the boiler for evaporating the water and steam was considered the basis for each horse power. Most of the boilers were built with very liberal steam liberating space. With the above units evaporation in boilers was about 3 pounds per square foot per hour at ratings which varied, of course, according to pressure and temperature conditions.

However, steam pressures are now used as high as 1200 pounds. The generally accepted pressure most largely used in modern lighting plants are between 300 and 400 pounds and with superheat that will bring the total temperature close to 800°. The various refinements and developments in boiler, stoker and furnace design have brought the work of the boiler up to such a point that we are now running even as high as 600 per cent of the old Centennial rating, so that this matter of per cent of rating is a very misleading one, especially to the layman who thinks that his boiler is being overworked or strained when operating above rating.

[3] Consulting Engineer, Indianapolis, Ind.

As a matter of fact, the logical rating to use is the one which will give the best efficiency with the different classes of equipment and accessories used in connection with the boiler. Maximum efficiencies are found in the neighborhood of 175 per cent of rating and efficiencies do not drop off very much from 125 up to 225 per cent of rating, so that unless there is some good reason for operating at very low ratings, say 100 per cent or under, these lower ratings are accompanied by actual loss in efficiency. In other words, there may be 12 to 15 per cent difference in efficiencies between 75 and 125 per cent of rating.

Furthermore, it may pay to run at higher ratings, due to the lower investment cost on the boiler equipment. Therefore, economical rating will usually be a compromise between efficiency, investment cost and furnace upkeep. The point, of course, can be reached where furnace upkeep will be too high under certain very high ratings and each case must be determined according to local conditions. However, ratings of 175 to 250 per cent are quite common in many medium size plants for continuous loads, and in the larger plants continuous ratings of 300 per cent and ratings up to 500 per cent on fluctuating loads are being carried right along.

This condition seems to be much better understood by many operators, of electrical power plants than of water plants. Therefore, the matter of boiler rating should be carefully gone into on any new plant or where there are a number of boilers. The question of efficiency as relating to rating should be carefully checked in order to determine just how many boilers should be used to carry the load. Of course, careful consideration must be given as to type and setting of boilers and combustion equipment as to just how much rating should be allowed to get the best result.

INCREASED BOILER PRESSURE

Increasing boiler pressure of steam will allow greater efficiencies in the operation of steam driven units. It can be stated that approximately at least $\frac{1}{4}$ pound in the steam consumption of the unit will take place for each 25 pounds increase in pressure.

SUPER HEATERS

Superheated steam is used to advantage on reciprocating engines or turbines. As such units depend upon the pressure and volume of

the steam for their power, the more nearly this steam approaches a perfect gas, the more efficiently it will be able to do its work. Superheated steam is more nearly a perfect gas than saturated steam.

The first point of advantage in using superheated steam in engines. comes from eliminating the initial condensation in the steam cylinder. Roughly about $7\frac{1}{2}°$ of superheat are required to eliminate each 1 per cent condensation at the point of cut off. The amount of superheat will vary with the different points of cut off.

The addition of a small amount of superheat will greatly increase the volume of the steam and the engine is therefore able to do much more work without having much additional heat applied to the steam. For example, a simple non-condensing Corliss unit using 26 pounds per steam horse power with saturated steam will probably only take from 18 to 20 pounds with steam superheated up to 100°. Furthermore, starting with superheat at the boiler, this can be made high enough to take care of all piping system losses up to the cylinders so that the steam coming to the engine will be without any moisture. This will do away with all condensation losses through the piping and up to the steam cylinders and leave the steam ready to start its work without any moisture content. This is of importance on any reciprocating engines. In turbine units about 1 per cent decrease in steam consumption occurs for about 12 degrees of superheat so that it can be readily figured that the superheated steam will be much more efficient than the saturated. A point not to be lost sight of is the fact that this will cut down the boiler load and make the work easier on the boiler. Such a saving reacts right through the prime mover and if the unit is condensing the lesser steam consumption makes the work easier on the condenser, by allowing some increase in vacuum which will further help to increase the overall efficiency.

Superheated steam also becomes especially valuable where steam is transmitted for any long distance.

Temperatures up to 450 or 500 degrees can be safely used on most units and pipe lines without causing any trouble. Cylinder lubrication in engine cylinders, however, should be looked into as it will usually require different oil and somewhat different methods of feeding.

POWER FACTORS

Power factor technically described is the cosine of the angle of lag. Power factor, of course, is a term which occurs only with the use of

alternating current and is dependent upon the Wattless current. Such Wattless current adds very little load, but it has the same heat effect, as though it were in phase with the line voltage on the system. Where power factor is low this energy is simply wasted into heat and excess heat causes final breaking down of insulation or short circuits. Low power factor increases the magnetizing current and decreases torque of induction motors. Such an increase of magnetizing current simply adds a load on the system and has to be paid for the same as current even though it does no useful work.

For example, should there be a power factor clause on your electric rate, stipulating that you must have a power factor of 85 per cent. If you are able to keep the power factor at only 75 per cent your bill will then become 85/75, or, for example, if you are using 20,000 kilowatt hour per month at one cent, your bill will be $226.00 instead of $200.00. This not only works a hardship on yourself, but also decreases the capacity of the generators.

Should electrically driven pumps using induction motors be used, the load should be carefully figured and such a motor selected as will operate practically at full load. Motors running at half load will have low power factor and low efficiency.

Where possible, it is often advisable to consider the use of synchronous motors, as this will give a high power factor and allow the better rate, should a power factor rate be in effect. Where pumps are being operated electrically with a generating unit in the pumping station, power factor correction will give increased capacity on the generator and, in many cases, overloaded machines can be made to give more load.

Low power factor may be likened to a disease. The low power factor simply results in handling a greater amount of current than is necessary for a given amount of energy.

PRIMARY CURRENT

Pumping units in many cases are operated with 220 volt motors where primary current at 2300 volts could just as well be used. Where this is possible it will result in a lower rate, as the primary current is generally lower in cost due to the discount, as compared with secondary service. Transformer losses and installation costs are also obviated.

Such items as the above should be given careful attention when installing new pumping equipment.

DOUBLE COAGULATION AT CINCINNATI[1]

By Clarence Bahlman[2] and E. B. Evans[3]

The success of double coagulation of turbid and highly polluted waters at Portsmouth, Ironton and other smaller towns in Ohio has been described in various reports of the Ohio Conference on Water Purification. At the suggestion of the Ohio State Department of Health, a thorough investigation of the process has been made at the Cincinnati plant. From the summer of 1926 to the early spring of 1927 double coagulation has been used in actual plant operation on 115 days, grouped into 11 experiments of from 4 to 17 days duration, and the results of the study are given in this paper.

Description of plant. The Cincinnati water purification plant is provided with 2 parallel-operated reservoirs for preliminary gravity sedimentation. There are no baffles and because of short circuits the theoretical 6-day period of retention is reduced to an actual retention of about 72 hours.

The three coagulation basins offer a 6- to 8-hour retention under normal rates. There are no true mixing chambers; the mixing of the chemical solution takes place during the passage through about 340 feet of 84 inch pipe leading to the basins.

The filters are provided with 14 inches of graded gravel and 30 inches of sand. The latter had an effective size of 0.34 mm. and a uniformity coefficient of 1.60 when the plant started operating in 1907. At the present time these measurements are 0.47 mm. and 1.22, respectively, and the distance from the sand surface to the top of the wash water gutter is 18 inches. The rate of filtration is 125 m.g.d. The filters are washed whenever the loss of head reaches a figure which experience has shown to be the maximum suited for the conditions encountered at the time. A 6-inch vertical rise is applied

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for 1 minute, followed by a final wash at an 18 inches rise for from 3.5 to 4 minutes.

Chlorine is applied to the filter effluent in sufficient amounts to maintain from 0.01 to 0.04 p.p.m. of residual disinfectant at the outlet of the filtered water reservoir, or about 5 hours subsequent to chlorination. The quantities used never have exceeded 0.30 p.p.m. Free chlorine is present in the distribution system during the winter months only.

Nature of the water at various stages of purification. The Ohio River normally shows an annual turbidity at the intake of about 300 p.p.m., but much higher turbidity prevails for about 20 per cent of the time. The average annual confirmed B. coli content has ranged from 1650 to 3350, with a normal value of about 2000 per 100 cc. Monthly averages occasionally approach or slightly exceed 10,000 per 100 cc.

The gravity-settled effluent from the preliminary settling reservoirs averages about 70 p.p.m. turbidity and 400 colon bacteria per 100 cc. This water is treated with an average of about 0.75 g.p.g. quick lime and 1.40 g.p.g. iron sulphate. A filter influent of about 17 p.p.m. turbidity and 70 coli is obtained.

For many years the unsterilized filter effluent has varied but little from an average of 4 coli per 100 cc. Monthly averages not exceeding 2 coli have been obtained over about 25 per cent of the time during the last 5 years. With maximum raw water pollution, however, the filter effluent often approaches 10 coli as a monthly average, and very rarely has averaged about 16 coli. At its worst the filter effluent may show 30 coli per 100 cc. over a period of a week or 10 days.

Without the use of chlorine, then, this plant, like most others, is unable to produce a water conforming to the well-known standards of purity.

The colon index of the chlorinated output, however, for 7 years has shown yearly averages which have varied only from 0.22 to 0.70 per 100 cc. It is only when the unsterilized filter effluent contains the larger numbers of coli that the chlorinated water may exceed 1 coli per 100 cc., and occasionally under adverse conditions it has closely approached the old 2 B. coli standard.

Reasons for investigating double coagulation. The main object of the investigation was to determine whether a water practically of standard quality could be produced by double coagulation without chlorination. Oftentimes we have been troubled with phenol tastes

in our water supply. In most instances the taste was not present in the raw water, and developed only after chlorination. Such tastes could be entirely eliminated by suspending the chlorination process. If the tastes could be noted in the raw water, the elimination of chlorine at least would considerably lessen the intensity of the nuisance.

Information was also desired as to whether the quality of the water delivered into service during the peak loads upon the plant could be bettered. It was also desired to determine the cost of the double process, and whether filter service could be increased and wash water saved at times when large numbers of algae were present.

Method of applying the primary coagulant. Alum was fed from a Gauntt dry-feeder into a solution tank, from which the solution was injected into the 60-inch raw water force mains, about 2100 feet from the point where these deliver into the primary settling reservoirs. The latter then function as primary coagulation basins. Under normal rates, the velocity in these mains is about 2.4 feet per second.

Plan of the experiments. Double coagulation was used whenever the raw water turbidity or colon content was such that more than 3 or 4 coli could be expected in the filter effluent, in the light of past experience.

No changes were made in the routine of plant operation, except, of course, that the improved quality of the water coming from the primary reservoirs usually permitted a reduction in the secondary coagulants, and made it possible to operate the filters for longer periods. Chlorine was used as always, in sufficient quantities to maintain the usual residual amounts.

The various results for each day of the experiment were averaged. At least 4 periods of single coagulation were selected which were comparable to the experiment either on the basis of raw water turbidity, 20°C. bacteria, or coli. These periods then were averaged, eliminating from consideration the turbidity, bacteria or coli of such that were of unlike magnitude to the average for the experiment. In this way an adjusted composite picture of single coagulation is obtained which shows approximately the same raw water turbidity, bacterial count and coli as were encountered in the experiment. All comparisons, of course, were drawn from data obtained at approximately the same time of the year.

Miscellaneous observations. Before discussing the main subject, certain observations may be mentioned at this point.

A most perfect mixing action seems to have been obtained in the force mains. The water was perfectly flocculated as it entered the reservoirs, and yielded a sparkling supernatant shortly after collecting in bottles. In actual practice, better and quicker results were obtained, with smaller doses, than were shown in laboratory bottle tests. It soon was evident that even an underdose of the primary coagulant would considerably lessen the load upon the succeeding processes, and therefore the alum was used in the minimum quantities necessary to secure good floc at the reservoir inlets. The maximum dose was 1.50 g.p.g., but for any experiment the average never exceeded 0.97 g.p.g.

The raw water pH values varied little from an average of about pH 7.5 during the summer, and this was reduced to about pH 7.3 by the primary coagulant. During the winter the raw water decreased to pH 7.1, and occasionally fell to pH 6.8. Free carbon dioxide varied but little from 2 p.p.m. in the river water, and the alum caused very little change except that the larger applications increased the carbon dioxide by 1.0 to 2.5 p.p.m. Raw water alkalinity averaged above 37 p.p.m. in only one experiment. The primary coagulant reduced the alkalinities from 2 to 10 p.p.m. At times when the larger doses of alum resulted in marked changes in pH value, alkalinity and free carbon dioxide, the application of lime in the secondary basins was very slightly greater than ordinarily would have been required for the dose of iron sulphate which was used at the time. This was necessary in order to maintain the customary amount of monocarbonate alkalinity in the secondary basins.

SUBORDINATE EXPERIMENTS

Two experiments are somewhat outside of the field which these investigations sought to cover, in that they dealt with low raw water turbidity (35 and 200 p.p.m.) accompanied with low coli content (450 and 530 per 100 cc.). With such raw water double coagulation is uncalled for because our ordinary methods then are able to produce an unsterilized filter effluent not exceeding 1 coli per 100 cc.

In both experiments less turbidity, 20°C. bacteria and coli arrived at the secondary basins than when single coagulation was employed, and there was a corresponding improvement in the filter influent and effluent. A lower colon index was obtained in the latter, but the difference is merely a matter of figures and not of sanitary significance. A marked reduction in the secondary chemicals was made pos-

sible, and these probably could be omitted if summer conditions prevail. Filter runs doubled in length, and a saving of 55 per cent in wash water was effected. The saving in the cost of chemicals averaged 20 cents per million gallons, but this just about equals the cost of labor for applying the primary coagulant, and therefore there was no monetary economy, aside from the value of the wash water saved.

There is no reason, then, for employing double coagulation when the plant is handling sub-normal loads. The same applies for average loads in summer, but at near-freezing temperatures it may be advisable to resort to the double treatment if there is any indication that the coagulation basins or filters are not functioning at their usual efficiencies.

Iron sulphate as a primary coagulant. The prices used in computing costs were as follows: alum $24.50, lime $9.27, iron sulphate $14.80, per ton delivered, chlorine $9.47 per hundred weight. With the above difference in cost of alum and iron, double coagulation involves additional expense for chemicals unless there is a saving in the secondary treatment of 1.25 g.p.g. of iron and 0.65 g.p.g. lime for each grain per gallon of alum used for primary coagulation. This led to a trial of iron sulphate, without lime, as the primary coagulant.

Although alum gave better coagulation and clarification than an equal amount of iron, bottle experiments seemed to indicate that the same end reaction could be expected if the quantity of iron sulphate was 50 per cent greater than the alum dose. The cost of this larger quantity of iron still would be less than the cost of the alum.

Three trials were made of iron sulphate as a primary coagulant. Better removals of turbidity, bacteria and coli were obtained than under comparable conditions of single coagulation, but the improvement was not as pronounced as when using alum. The added iron sulphate precipitated from solution and caused no increase in soluble iron at the secondary basins, but the rate at which the floc deposited was quite slow. Wind action and slight increases in velocity through the reservoirs interfered noticeably with the sedimentation. In actual practice iron sulphate did not work nearly as well as in the laboratory; with alum the converse was true.

Trials were made with half-and-half mixtures of alum and iron, but all experiments led to the conclusion that better primary coagulation, and better results at subsequent stages, could be obtained from alum than from a dose of iron sulphate of equal cost.

TABLE 1

Results of the six major experiments arranged in order of increasing B. Coli content in raw water

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Results of the six major experiments arranged in order of increasing B. Coli content in raw water

	EXPERIMENT 7		EXPERIMENT 11		EXPERIMENT 1		EXPERIMENT 4		EXPERIMENT 8		EXPERIMENT 5	
	Single	Double	Single	Double	Single	Double	Single	Double	Single	Double	Single	Double
Turbidity p.p.m.:												
Raw	140	145	395	390	385	500	720	700	450	450	720	700
Effluent primary reservoir	38	13	120	26	95	11	130	24	85	22	135	32
Effluent secondary basins	16	10	19	10	17	9	20	13	22	12	22	12
20°C. bacteria per cubic centimeter:												
Raw	22,300	22,600	69,600	69,000	5,650	4,700	10,400	9,700	61,000	62,600	15,600	16,000
Effluent primary reservoir	7,000	2,500	16,000	11,800	670	140	1,120	325	7,100	4,700	1,950	700
Effluent secondary basins	1,380	750	2,175	2,400	145	105	110	215	1,160	1,170	225	170
Filter effluent	145	75	285	310	6	9	5	9	125	135	10	9
Chlorinated	7	2	15	16	30	7	41	20	8	1	60	40
Confirmed B. coli per 100 cc.:												
Raw	1,180	1,000	1,760	1,800	3,545	3,570	5,250	5,500	6,400	7,000	12,300	12,000
Effluent primary basins	275	65	620	165	780	23	850	170	820	220	1,590	140
Effluent secondary basins	65	55	64	22	210	36	165	37	345	54	220	29
Filter effluent	4.42	1.40	5.00	0.59	3.70	0.86	11.00	0.80	13.57	2.67	12.10	2.90
Chlorinated	0.08	0.00	0.35	0.06	1.30	0.00	0.83	0.00	0.30	0.00	1.32	0.64
Chemical doses:												
Primary, g.p.g. alum		0.54		0.57		0.62		0.97		0.90		0.94
Secondary, g.p.g. lime	0.82	0.69	0.91	0.81	0.69	0.50	0.76	0.54	0.82	0.69	0.78	0.77
Secondary, g.p.g. iron sulphate	1.63	1.30	1.76	1.45	1.25	0.73	1.46	0.71	1.70	1.36	1.57	1.08
Secondary, p.p.m. chlorine	0.24	0.27	0.18	0.16	0.16	0.22	0.18	0.21	0.27	0.25	0.19	0.24
Cost of chemicals per million gallons	$2.49	$3.11	$2.66	$3.39	$1.92	$2.40	$2.29	$3.16	$2.52	$3.84	$2.41	$3.52
Additional cost of double coagulation		$0.62		$0.73		$0.48		$0.87		$1.32		$1.11
Filter Service, hours	20.9	28.3	21.0	20.2	30.9	51.6	32.5	48.1	23.8	20.5	34.6	45.9
Increase due to double coagulation, per cent		35.0		0.0		66.0		48.0		0.0		32.0
Wash water, per cent	1.80	1.26	1.63	1.72	1.28	0.69	1.03	0.66	1.53	1.71	1.02	0.75
Saving due to double coagulation, per cent		30.00		0.00		46.00		36.00		0.00		26.00

TABLE 2

Summarized comparison of single and double coagulation

	SINGLE COAGULATION	DOUBLE COAGULATION
Turbidity:		
Raw water	470	480
Effluent primary reservoirs	100	21
Effluent secondary basins	19	11
20°C. bacteria:		
Raw water	30,800	30,800
Effluent primary reservoirs	5,650	3,360
Effluent secondary basins	860	800
Filter effluent	96	90
Chlorinated	27	31
B. coli per 100 cc.:		
Raw water	5,075	5,145
Effluent primary reservoirs	820	130
Effluent secondary basins	175	39
Filter effluent	8.30	1.54
Chlorinated	0.70	0.12
Chemical doses:		
Primary, g.p.g. alum		0.76
Secondary g.p.g. CaO	0.80	0.67
Secondary $FeSO_4$ g.p.g.	1.56	1.11
Secondary p.p.m. Cl	0.20	0.23
Cost of chemicals per million gallons	$2.38	$3.24
Additional cost of double coagulation per million gallons		0.86
Filter service:		
Hours	27.3	35.8
Increase due to double coagulation (per cent)		31.1
Per cent wash water	1.38	1.13
Saving due to double coagulation (per cent)		18.1

MAJOR EXPERIMENTS

The results obtained in the six principal experiments are shown in table 1. Tables 2, 3, and 4 are convenient recapitulations from which most of the following discussions are drawn.

It has happened that the chlorine doses in some of the double coagulation trials were slightly greater than in corresponding periods of single coagulation. This is mere coincidence; the quantity used always being such that approximately the same residual amount was maintained in all of the comparative periods. It is the quality of the unsterilized filtered water which will reveal any merits which the double process might possess, and the tabulations might be terminated at this stage. The results after chlorination are of interest, however, in connection with the question as to the effect of double coagulation upon the quality of the final plant output.

TABLE 3

Comparison of percentage removals in single and double coagulation

	PERCENTAGE REMOVALS					
	Turbidity		20°C. bacteria		B. coli	
	Single	Double	Single	Double	Single	Double
Based on original raw water value						
In primary reservoirs	78.8	95.6	81.7	89.1	83.8	97.5
In secondary basins	17.2	2.1	15.6	8.3	12.7	1.8
By filters	4.0	2.3	2.5	2.3	3.3	0.7
Based on initial value for each process						
In primary reservoirs	78.8	95.6	81.7	89.1	83.8	97.5
In secondary basins	81.0	47.6	84.8	76.2	78.7	70.0
By filters	100.0	100.0	88.8	88.8	95.3	96.1

A discussion of the results follows.

Turbidity. The turbidity coming from the preliminary reservoirs was much lower when the primary coagulant was used, and in general was of the same magnitude as, and occasionally lower than, the turbidity of the filter influent in single coagulation. A further reduction occurs in the secondary basins, so that only about one-half the usual amount of suspended matter comes to the filters when double coagulation is practiced.

If the turbidity of the primary-settled water is very low, as in the subordinate experiments, there will be little, if any, deposition in the secondary basins. Some floc always will be carried to the filters.

20°C. Bacteria. A substantially greater removal of bacteria as enumerated by the 20°C. counts was obtained from the primary process when alum was used. In spite of this, however, 4 of the 8 experiments showed bacterial counts in the filter influent and effluent which were not materially different in single and double coagulation. As regards bacterial counts, no great advantage of using the primary coagulant could be recognized by the time the water comes to the filters.

Percentage removals. The combined average efficiencies of the 6 principal experiments are shown in table 3.

TABLE 4

Recapitulation of coli data in single and double coagulation

EXPERIMENT	B. COLI PER 100 CC.								
	Raw water	Effluent from primary reservoirs		Filter influent		Filter effluent		Chlorinated	
		Single coagulation	Double coagulation	Single coagulation	Double coagulation	Single coagulation	Double coagulation	Single coagulation	Double coagulation
3	450	71	31	40	20	1.00	0.00	0.00	0.00
2	530	52	6	40	6	0.85	0.50	0.05	0.00
7	1,100	275	65	65	55	4.42	1.40	0.08	0.00
11	1,800	620	165	64	22	5.00	0.59	0.35	0.06
1	3,550	780	23	210	36	3.70	0.86	1.30	0.00
4	5,400	850	170	165	37	11.00	0.80	0.83	0.00
8	6,700	820	220	345	54	13.57	2.67	0.30	0.00
5	12,000	1,590	140	220	29	12.10	2.90	1.32	0.64

Naturally, very much greater removals in the preliminary reservoirs are obtained when a coagulant is used. The difference is especially marked for turbidity and coli, and less so for 20°C. bacteria.

When the primary coagulant is used, less impurity as measured by turbidity, bacterial counts and coli comes to the secondary basins, and the latter then lag behind their normal efficiencies. As mentioned above, there is little and often no removal of turbidity in the coagulation basins if extremely low turbidity is applied to them, and in experiments 1 and 7 there was little or no removal of coli in these basins.

It is interesting to note that there is no similar reduction in filter efficiency. With only about one-fourth the usual number of coli

coming to the filters after double coagulation, the filters still retain their normal efficiency of well above 95 per cent.

B. coli removals. The coli data furnish the crucial evidence from which the comparative merits of single and double coagulation may be judged. The summarized averages for each of the 8 experiments are given in table 4, and these will be discussed from the bearing which they have on the three major questions which this investigation has sought to answer, namely (1) whether double coagulation introduces additional safeguards in plant operation (2) whether it improves the quality of the final chlorinated output and (3) whether chlorination can with safety be suspended when double coagulation is practiced.

1. Additional safeguards of double coagulation. A general idea of the performance of the two processes in respect to lowering coli density may be obtained from table 2. Attention is directed to the following facts:

1. That with an average raw water colon content in the neighborhood of 5100 per cubic centimeter, (*a*) only 130 coli were delivered to the secondary basins when the primary coagulant was used, as compared with 820 when gravity sedimentation alone was functioning, (*b*) that the water coming from the preliminary reservoirs, when using alum, contained fewer coli than the filter influent in ordinary operation, (*c*) that the filter influent in double coagulation averaged but 39 coli per 100 cc., as compared with 175 in single coagulation.

2. The lowered colon content of the filter influent in double coagulation has effected a tremendous improvement in the coli index of the filter effluent, as shown by the general average in table 2 and by the individual averages in table 4.

3. The filter influent has exceeded 50 coli per 100 cc. in only two of the 8 experiments. Past experience has shown that this is the maximum number of influent coli consistent with the production of an effluent not exceeding 2 B. coli per 100 cc.

4. Figure 1 shows the coli expectancy in the filter effluent, as raw water pollution increases. The flattening effect of double coagulation upon the curve is quite marked. Even with 12,000 raw water coli, the filter effluent may, according to the curve, be kept well under 4 coli by double coagulation, whereas 13 or more may be expected with single coagulation. Graphs showing coli at the outlet of the primary reservoirs, and in the filter influent, are so similar to figure 1 as to be practically superimposable. For convenience the maximum numbers at the above two stages of purification, in single and double coagulation, have been inserted in figure 1.

5. The colon index of the chlorinated water after double coagulation has been lower than for comparable periods of single coagulation.

6. Each of the experiments was started at the beginning of a period of marked increase in raw water pollution. Ordinarily a subsequent increase of turbidity, bacteria and coli would have appeared at all stages of the purification process, but, with primary coagulation, no evidence of the increased raw water pollution was noted at the secondary stages. Often the water coming to the plant during the flooded

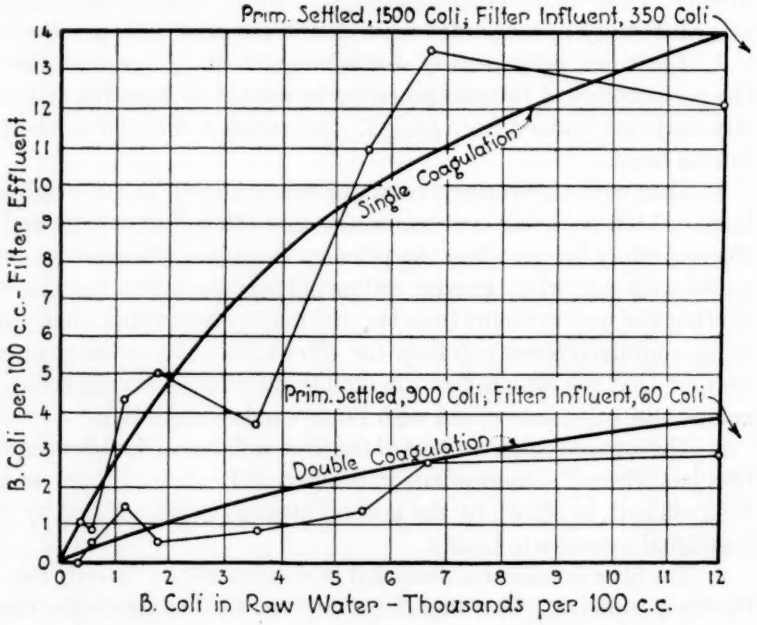

FIG. 1. EFFECT OF DOUBLE COAGULATION ON FILTER EFFLUENT

river condition was more favorable as regards turbidity, bacteria and coli, than during the single coagulation period of normal turbidity and pollution, immediately preceding the use of alum.

The coagulation basins, the filters and the chlorination process, then, receive lighter burdens when the double process is used, and the chlorination process comes very much nearer to being a true factor of safety. Obviously a highly desirable additional safeguard is introduced by practicing double coagulation when adverse conditions are encountered.

2. Effect upon quality of final output. All the experiments without exception have shown, after chlorination, either no coli, or a lower colon index than was obtained by single coagulation. It seems academic and not practical, however, to consider a water of zero index as any more safe than one which shows some coli, but materially less than are permitted by our present drastic standard. It appears in table 4, however, that a more significant deviation between the colon indices of the final chlorinated water is noted when the raw water coli approaches or exceeds 3550 per 100 cc.

Positive tests in the chlorinated water often become more frequent when coli in the filter effluent begin to soar. To remedy this by increasing the chlorine application not only is a makeshift policy which relies upon the last weapon of defense for obtaining a satisfactory final water, but involves a delay of two or three days before one can determine whether coli density actually has increased, or whether the first positive tests were mere chance occurrences which are apt to be observed when many samples of the same water are examined.

It may be stated, then, that no significant betterment in the final output is brought about by double coagulation if the raw water does not exceed 3500 coli per 100 cc. When more than this number are present, however, the colon content of the filter effluent may be kept so low by practicing double coagulation that the index after chlorination not only will be more favorable than under comparable conditions of single coagulation, but is certain to be well within the standard requirements.

3. Does dougle coagulation, without chlorination, afford adequate protection? Table 4 shows that double coagulation has produced an unchlorinated water conforming to the 1914 Treasury Department standard in the 6 experiments having less than 6000 coli in the raw water, but that the filter effluent slightly exceeded the standard when more pollution was encountered. Experiment 8 was a mid-winter trial, with floating ice in the reservoirs, and the higher colon index of the filter effluent after double coagulation can be attributed to sluggish chemical reactions, resulting in a filter influent slightly in excess of 50 coli per 100 cc. In experiment 5 the higher than expected index of the filtered water must be charged to a temporary falling off in filter efficiency, because a very much better performance should have been obtained with a filter influent containing as few as 29 coli. Except for these rather unusual occurrences, double coagulation without chlorination comes very near to satisfying specifications which for

more than 10 years were considered as adequately defining a pure water.

The new 1925 standard, however, calls for a colon index not in excess of 1 per 100 cc. In 3 of the 8 experiments double coagulation failed to conform to this standard. Mostly it is only during subfreezing weather, or with excessive raw water pollution, that the double process falls short of the goal.

The consumer, however, is entitled to full protection at all times. One can not exclude the probability that unexpected, temporary departures from normal efficiency may occur at any time, even though they may actually have occurred only under unusual stress. With the new United States Public Health standard as the criterion, double coagulation without subsequent chlorination does not afford adequate protection when the degree of pollution is such as that of the Ohio River.

This, of course, in no way lessens the usefulness of the process, in conjunction with chlorination, at times when the plant is carrying excessive loads.

Having so closely approached the approved standards by double coagulation, it has been an easy matter to remove the few remaining colon bacteria by utilizing the well-known sterilizing action of lime. Many trials of heavy lime treatment at this plant have indicated that a coli-free filter effluent can be produced with certainty from a water containing five or more times as many coli as the maximum number likely to come to the secondary basins when using a primary coagulant. The filtered water then showed not to exceed 1 p.p.m. of hydroxyl alkalinity, but the majority of the samples were slightly under the caustic point. For additional safety when disinfection is suspended, the water in the secondary basins may be held consistently above causticity.

Actual operation without chlorine. In December, 1926, obnoxious phenol tastes appeared in the city tap water. Double coagulation was started and chlorination was suspended. The tastes disappeared completely at all parts of the city within 48 hours. The prompt recurrence of the trouble when disinfection was resumed, 10 days thereafter, is good confirmatory evidence of the continued presence of the taste-producing compounds during the period, and demonstrates that the consumer may be spared discomfort by suspending the disinfection process, when the latter causes the water supply to be distasteful.

In this first actual elimination of disinfection, heavy lime treatment was not used during the first three days, or until the first available tests indicated that coli averaging 3.5 per 100 cc. had appeared in the water. Excess lime treatment then was started, and for the following 7 days a coli-free water of unusually low bacterial count was delivered, as shown by daily samples from two or more sections of the city, in addition to the routine plant samples. By resorting to double coagulation combined with excess lime treatment about 24 hours before stopping chlorination, there will be no break in the zero coli records of the plant output, and the water will be the equal in quality of that produced when chlorine is used.

Chemical doses. As mentioned earlier, comparatively small applications of alum sufficed to accomplish marked improvement.

With turbidities not exceeding 700 p.p.m. the saving in secondary chemicals when using alum, in summer, was such that the total quantity of the three coagulating chemicals used in double coagulation was less than the total of the two used in ordinary practice. With the more sluggish winter reactions, however, or with higher raw water turbidity at any time, the amount of lime and iron saved as the result of using the primary coagulant was less than the quantity of alum applied. The total quantities used in double coagulation, however, have never exceeded the total employed in single coagulation by more than 0.50 g.p.g.

Coagulation and filtration efficiencies naturally fall off as water temperatures reach 40°F., or lower, and at such times the water in the filtered reservoir often loses its customary summer brilliancy. It has been our experience that doses of not less than 0.80 g.p.g. lime and 1.25 g.p.g. iron are then required, regardless of low turbidities and bacterial content that may prevail at the time. Colloidal detritus which is so useful for matte formation in warmer weather is lacking, and it is necessary to shorten the filter runs. Usually this is more efficacious in combating smoky water than a substantial increase of chemicals. Often a combination of both remedies is not entirely successful in restoring brilliancy.

The action of double coagulation at times when the above trouble is encountered was somewhat disappointing. When comparing the lime and iron doses of the winter trials of double coagulation with the average doses of these secondary chemicals in single coagulation, a material saving is indicated, as shown in table 1, but no saving of wash water was obtained. Any attempt to reduce materially the lime and

iron below the doses which were adequate immediately preceding a trial of double coagulation often resulted in smoky water. Nor was it possible to lengthen the filter runs beyond the customary period for single coagulation, even though the turbidity coming from the primary reservoirs did not exceed 30 p.p.m. Just as much vigilance in filter operation was required as in regular practice.

In winter, then, the use of a primary coagulant may in the long run permit of some saving of secondary chemicals, but frequently this will not be possible, nor can the filters be operated to materially higher losses of head. In general there will be no saving of wash water during cold weather.

Whenever smokiness occurred during double coagulation, however, it was easily and certainly corrected by slightly decreasing the filter service, whereas in single coagulation both an increase in chemicals and a reduction in filter runs frequently did not clear up the water satisfactorily.

Effect on length of filter service and quantity of wash water. The effect of two prior periods of coagulation upon the filter influent was such that considerably longer periods of service were obtained from the filters during summer and early autumn. Filter runs were increased from 32 to 66 per cent and a saving of from 26 to 46 per cent of wash water was possible.

In winter, however, it was impossible to obtain longer filter runs than in single coagulation, as mentioned earlier. This was especially true when ice was present in the reservoirs.

In general, the greatest effect of double coagulation, as regards lengthened filter service and decreased wash water, was noted with waters of lower turbidities, except that in winter there was little or no benefit from the process.

Excessive rainfall occurred during the summer of 1926, and at no time were we troubled with microörganisms in sufficient numbers to shorten seriously the filter runs. If the latter decrease to 6 hours or less at times of heavy water consumption, it becomes difficult to maintain an adequate supply of wash water. Two- or three-fold increases in chemicals applied to the coagulation basins have been of no help. An answer to the question as to whether double coagulation will be of assistance when excessive algae content seriously shortens filter service cannot be given until an opportunity to try the process is afforded.

Comparative costs. At plants using alum as the coagulant, splitting the dose into primary and secondary applications seemingly will not involve any material increase in cost because, according to our results, the total dose in double coagulation is slightly greater than the quantities used in single coagulation only at times of maximum turbidity and pollution in the raw water.

In our case, the cost of the lime and iron saved in the secondary treatment was less than the cost of the primary alum dose. The greatest additional cost of double coagulation naturally will occur during the winter when high raw water turbidity is encountered. In our 6 principal experiments the maximum additional cost for chemicals was $1.32 per million gallons and the average additional expense for summer and winter conditions was 86 cents per million gallons.

In view of the many advantages of the double process this expense is not prohibitive. It is estimated that double coagulation is advisable at our plant for not more than 40 per cent of the time. The additional cost then would be about $6500 per annum. This, distributed over the entire year's output, is equivalent to 36 cents per million gallons.

SUMMARY AND CONCLUSIONS

When double coagulation is used at this plant, only about one-half of the usual turbidity and about one-fourth of the coli will come to the filters. Plant operation becomes more responsive to control, additional safeguards are introduced, and the chlorination process becomes more truly a factor of safety.

The double process may be expected to produce a filter effluent not exceeding 1 colon organism per 100 cc. if the raw water colon content does not exceed 2000, and not exceeding 4 coli when the raw water contains as many as 12,000 per 100 cc. With initial pollution reaching or exceeding 3500 coli, the colon index of the final chlorinated output after the double process is materially lower than when using single coagulation.

On the basis of the 1925 United States Public Health standard, double coagulation without chlorination is hardly adequate to produce a uniformly satisfactory water, but when combined with excess lime treatment it consistently has produced a coli-free water.

There is a saving of secondary chemicals, filter runs are lengthened and wash water is saved by the double process at all times except during midwinter.

Double coagulation has involved a slight additional expense which is not considered prohibitive in view of the manifold actual and potential advantages of the process.

REFERENCES

Ohio Conference on Water Purification, State Department of Health, Columbus, Ohio. Second Annual Report, 1922, p. 136. Third Annual Report, 1923, p. 47. Fourth Annual Report, 1924, p. 65. Fifth Annual Report, 1925, p. 51. Sixth Annual Report, 1926, p. 37.

WATER SUPPLY PROGRESS IN THE ROCKY MOUNTAIN REGION[1]

By Dana E. Kepner[2]

During the past year the Rocky Mountain region has seen much activity in the water works field. Although no particularly large projects have been under way, the several small plants constructed, the many improvements made in existing plants, and the general awakening of interest in modern practice, characterize 1927 as a definitely progressive water works year for this part of the country.

With the growth of our relatively young western cities and towns their water supplies are being developed in general much as those of the older, eastern municipalities were developed during their corresponding period of growth. As our streams, once clean and reasonably satisfactory as sources of domestic water supplies, become contaminated and unsatisfactory, due to the increase in population and industrial development, filters and sterilizing plants must be provided. Similarly, with the corrosion and consequent leaking of well casings and the encroachment of habitation upon land adjacent to wells, many ground water supplies are becoming more or less subject to contamination and either sterilization is required or a new supply must be developed. Coincident with these changes in conditions affecting the sources of the supplies, changes have taken place in the attitude of the people toward the quality of water furnished them. We are becoming more and more particular about the physical, chemical and bacteriological characteristics. We want water which is clear, colorless, and preferably brilliant; odorless and pleasant to the taste; soft and generally free from objectionable chemical substances; and safe at all times from the entrance of disease producing bacteria.

The progress in water supply development in the Rocky Mountain region during 1927 may be seen in the following brief summary:

[1] Presented before the Rocky Mountain Section meeting, February 23, 1928.

[2] Sanitary Engineer, State Board of Health, Denver, Colo.

New water supply systems were constructed at Kremmling and Ovid, Colorado; Yoder, Wyoming; and Melrose, New Mexico.

New sterilizing plants of the liquid chlorine type were installed on well water supplies at Arvada, Manzanola and Sterling, Colorado; and on surface water supplies at Craig, Colorado Springs and Johnstown, Colorado; Huntington and Tooele, Utah; and Nogales, Sonora (Mexico).

Redwood, continuous stave pipe, 40 inches in diameter, was chosen by the North Side Water Works at Pueblo, Colorado, to carry settled and chlorinated water from the purification plant to the pumping plant. Cement-lined pipe was used entirely in extensions to the distribution system at Roswell, New Mexico, to prevent corrosion trouble. Centrifugal concrete pipe was chosen at Phoenix, Arizona, to replace 5 miles of 36 inch redwood pipe on the Verde supply.

Electric pumping plants were installed to take the place of steam plants at Tucson and Puro, Arizona; and Denver, Colorado. Diesel engine driven pumps superceded steam pumps at Roswell, New Mexico.

The policy of sterilizing new, large mains with liquid chlorine before placing them in service was adopted at Denver, Colorado.

Extensive miscellaneous changes in and additions to existing water supplies have been made at Sterling and Littleton, Colorado; American Fork, Beaver, Cedar City, Ephraim, Fairview, Fillmore, Lewiston, Midvale, Salina, Salt Lake City and Vernal, Utah; Tucson and Phoenix, Arizona; Alamogordo, Magdalena, Roswell, Santa Fé and Silver City, New Mexico.

Studies of cross-connections between the pipes of the public water supplies and those of private supplies, to determine and remedy possible pollution hazards, were carried on in Denver, Fort Collins, Grand Junction and Loveland, Colorado.

Plans were being prepared for modern filtration plants at Roswell, Colorado, and Farmington, New Mexico; for a softening and iron removal plant at Albuquerque, New Mexico; for new supplies at Jackson and Glendo, Wyoming; and for general changes in the existing water works systems at Buffalo, Wyoming, and Lafayette, Colorado.

Copper sulphate treatment to prevent objectionable tastes due to algae and other microörganisms growing in reservoirs was adopted this year at Grand Junction and Johnstown, Colorado, and at the Mountain Dell supply of Salt Lake City, Utah. Reservoirs were stocked with trout to overcome algae difficulties at Albuquerque, Gallup, and Wagon Mound, New Mexico.

The control of chlorination by means of regular, frequent and systematic ortho-tolidin tests for residual chlorine, was carried on at Arvada, Canon City, Colorado Springs, Fort Collins, Fountain, Grand Junction, Gunnison, Johnstown, Longmont, Loveland, Manzanola, Montrose, Pueblo, Rocky Ford and Sterling, Colorado; Las Vegas, New Mexico; Puro, Winslow and Tucson, Arizona; and Nogales, Sonora (Mexico).

Experiments with sodium aluminate to aid in coagulation reactions were carried on at Denver and Pueblo, Colorado; and at Cheyenne, Wyoming.

Looking a year or two into the future, several further developments appear probable. Softening plants will undoubtedly be constructed

at several cities where waters with hardness factors of from 400 to 900 parts per million (23 to 53 grains per gallon) are now being used. A modern filter plant with provision for softening will probably be constructed at one of the largest cities in the region. Several new water supplies will be constructed at towns not now provided with them, and many existing supplies will be improved, or extended, or provided with filters, chlorinators and aerators.

WATERSHED SANITATION[1]

By Paul S. Fox[2]

My story deals with the water supply of the City of Santa Fé, New Mexico. The source of the supply is Santa Fé Creek which is a typical mountain stream. The stream has its beginning at Santa Fé Lake, a beautiful little jewel nestled in a green forest at the foot of Lake Peak. The lake is at an elevation of something over 11,000 feet. The water in the stream is principally derived from melting snows and it is consequently very soft. At the peak of the spring run-off the total solids are less than 30 p.p.m. and these gradually increase, as the run-off diminishes, up to a maximum of about 100 p.p.m.

The system is owned and operated by a private corporation, the New Mexico Power Company, and was formerly owned and operated by the Santa Fé Water and Light Company. The original company constructed an earth fill dam across the mouth of the canyon which impounds about 125 million gallons of water. A by-pass was built around the reservoir to take care of flood waters. In order to supply adequate pressure to the higher portions of the city, when the water level in the reservoir was low, water was diverted at a point about 1 mile above the reservoir. However, when the reservoir is full, there is ample pressure in all parts of the city. The old company had its troubles in the way of supplying sufficient water. The entire city was on an unmetered flat rate basis and consequently there were several times when a serious water shortage was imminent. The 125 million gallons in the reservoir was a scant three months supply.

This is now history. The city is now practically all metered and the New Mexico Power Company has constructed another earth fill dam in the canyon at a point about 3 miles above the original reservoir. This dam impounds about 210 million gallons, which now increases the storage to about 335 million gallons. The distribution

[1] Presented before the Rocky Mountain Section meeting, February 23, 1928.

[2] Chief, Division of Sanitary Engineering and Sanitation, Bureau of Public Health, Santa Fé, New Mexico.

system was put into first class shape by replacing many of the small wrought iron and galvanized pipe by larger cast iron mains.

Along with these many valuable improvements it was desirable to improve and conserve the sanitary quality of the water. The watershed is practically all covered with virgin forest. There is no habitation except the Ranger's Cabin at Granite Point and the Elk's Cabin at the end of the road which goes up the Canyon. This Elk's Cabin, on land leased from the Forest Service, was built as a summer resort, but has not been used as such in many years. This cabin is about 10 miles above the old reservoir. The canyon is very narrow with precipitous slopes which render the country on both sides of it almost inaccessible.

About three years ago, through a coöperative agreement between the old water company and the Forest Service, a drift fence was constructed on both sides of the canyon at the forest boundary and grazing was prohibited on the watershed. I say grazing was prohibited, which seems to be next to impossible. It was reduced, however, to a minimum, and the improvement in the quality of the water, from a bacteriological viewpoint was remarkable. In the three years that have passed, there has been rapid growth of willows and alders along the banks of the stream which are invaluable in the prevention of erosion.

Upon the completion of the new reservoir, the manager of the New Mexico Power Company, having become familiar with the improvement in the quality of the water following the restriction of grazing, was anxious to take such steps as might further assure the continued safety of the supply. Unfortunately the Santa Fé Canyon begins right at the edge of the City and it furnishes an excellent recreational spot for residents during the summer months. In imposing any restrictions upon the watershed, this recreational use of the canyon had to be taken into consideration.

Although the Forest Service had provided camp facilities at several locations, camping and picnicking were promiscuous. On almost any day during the summer months one could ride up the canyon and see anywhere from one to a half dozen camps pitched right on the banks of the stream, none of them utilizing the facilities which had been provided.

Shortly after the New Mexico Power Company had taken over the management of the water system, a conference was called by W. W. Neilsen, Manager. Mr. Frank Andrews, Supervisor of the Santa

Fé National Forest, Francis C. Wilson, Attorney for the Company, and the writer were present. Section 3564 of the 1915 New Mexico Code empowers the governing body of a municipal corporation to exercise control over a watershed for a distance of 5 miles above the point of diversion. All of the land in question was under the control of either the Company or the Forest Service. It seemed to be understood by all parties concerned that some restrictions should be made regarding the recreational use which was to be made of the watershed, and that these restrictions should be in the form of an ordinance passed by the City Council. Each of the above parties made a list of the things which should be embodied in the ordinance. After giving the matter considerable thought the following ordinance was developed by the Company and given publicity. A group of representative business men were taken on an inspection trip up the canyon and various dangers which were in existence were pointed out in detail. The plan and the ordinance were presented before the various service clubs and their support enlisted. The ordinance was presented to the City Council and it was passed. The Forest Service and the Company employ a patrolman during the summer months who polices the canyon.

The ordinance is as follows:

ORDINANCE 601

FOR THE PROTECTION OF THE WATERSHED OF THE SANTA FÉ RIVER, PROVIDING FOR THE POLICING OF THE SAME, AND FOR PENALITIES FOR VIOLATION OF THIS ORDINANCE

Be it ordained by the City Council of the City of Santa Fé:

SECTION 1. For the protection of the water supply of the City of Santa Fé, bathing, camping, fishing, picnicking, and the grazing of all domestic live stock within the Santa Fé River Watershed between the dam of the old Reservoir and Monument Rock are hereby forbidden, except that camping or picnicking shall be allowed at such point or points as shall be agreed upon between the City Council, the New Mexico Power Company and the United States Forest Service, and then only under such rules and regulations as may conform and be in accord with the rules and regulations of the United States Forest Service, adding thereto such rules and regulations not in conflict therewith as may seem best to the City Council for the purposes of the protection of the water supply of the City of Santa Fé from any kind or character of pollution, or anything which would tend, in the opinion of the Sanitary Engineer of the State of New Mexico, to pollute or destroy or impair the potability of the water supply of the City of Santa Fé.

SECTION 2. Any violation of this ordinance, or any violation of such rules and regulations as may be jointly agreed upon between the United States Forest Service, the New Mexico Power Company, and the City Council of the City of Santa Fé, which said rules and regulations shall be prominently displayed at various points in the Santa Fé River watershed between the Old Dam and Monument Rock, shall be punished by a fine of not less than ten dollars ($10.00) nor more than one hundred dollars ($100.00) or imprisonment in the City Jail for not less than five (5) nor more than sixty (60) days for each offence, or both; and domestic live stock found grazing in said area without a permit from the United States Forest Service shall be taken up and held subject to the payment of the fine herein provided for by the owner of such domestic livestock, and in default of such payment said domestic live stock shall be sold at public auction and the proceeds applied first to the payment of said fine and proceedings, and the balance, if any, turned over to the owner.

WATER SUPPLIES OF THE MISSISSIPPI COAST

By W. A. Kramer[1] and M. P. Hatcher[2]

Bay St. Louis, Pass Christian, Gulfport, Biloxi, Ocean Springs, and Pascagoula form the important cities along the 85 miles of the Mississippi coast line bordering the Gulf of Mexico.

Remarkable development and industrial expansion has taken place in this area during the last two years. This section served by two great railroad systems and Gulfport engaged in world wide commerce through its deep water seaport has given great impetus to the nascent industrial kingdom. Manufacturers are finding that the low priced lands of southern Mississippi, with abundant railroad facilities, reaching north, east and middle west are solving problems that have handicapped their operations in the more congested manufacturing sections of other states.

When water is used in large quantities for other than drinking, other characteristics must be examined. The clear and sparkling water of a spring, refreshing and suggestive of purity will not always most economically satisfy the thirst of the boiler as it does our aesthetic sense.

One is aware that water supply is one factor to be considered in choosing the location of industrial plants. This factor has already been discussed by Collins.[3]

In historic and prehistoric days the question of water supply was of no importance. In our mechanical age the constantly increasing use of water for other than cleansing purposes has made more difficult the problems of water supply.

At the present time ground waters and surface waters furnish the principal supply throughout the United States. Many cities formerly supplied by ground water supply are now investigating surface water supply because the former is inadequate to meet the increasing demand of the public for plenty of good water. The practice of col-

[1] Gulfport, Mississippi.

[2] Sanitary Engineer, Burns & McDonnell Engineering Company, Kansas City, Mo.

[3] Trans. Am. Inst. Chem. Eng., 22: 27–33, 1925.

lecting and storing rain water in reservoirs is rapidly yielding to the installation of modern filtration plants with surface water as the source of supply.

Ground waters furnish supplies to many small cities, and as a rule of better quality from a sanitary standpoint than surface waters, but in many cases will not be wholly satisfactory until softening plants are installed.

SOURCE OF SUPPLY

The most important artesian well area in the United States is that which borders the Gulf of Mexico. The conditions here are very favorable for artesian wells and the strata furnish exceedingly valuable source of water supply for cities in this region.

The term artesian according to Turneaure and Russell[4] was formerly applied exclusively to flowing wells and is derived from the word Artois, the name of a province in France where such wells were first exclusively bored. More recently the term is applied in a broader sense, according to which an artesian well may be defined as one in which the water is drawn from a porous stratum underlying a relatively impervious one. Whether it will overflow depends on local conditions.

Lowe[5] states "that artesian wells can be obtained all along the coast at depths from 450 to 800 feet, the flow from deeper horizons being very strong and the water is good for all purposes."

According to the United States Geological Survey[6] with few exceptions the entire State of Mississippi lies in the Coastal Plain. A study of the geologic conditions of the state shows that there is a great thickness of unconsolidated sands interbedded with water tight clays which form large underground reservoirs for the accumulation of water. The rain water enters the upturned edges of these open textured sands, collects in these wide reservoirs and thus becomes available as well water.

The average rainfall in inches each year in the Gulf Coast region is about 62. The greatest annual precipitation was 101.4 in Bay St. Louis in 1900.

The capacity of an artesian source as good as the one found in the Gulf region is of little importance. The total amount of water cap-

[4] Public Water Supply, 1st Ed., page 39, John Wiley and Sons, Inc.

[5] Director, Mississippi Geological Survey, personal letter.

[6] Underground Water Resources of Mississippi, Water Supply Paper 159.

FIG. 1. WELL AT GULF HILLS, MISSISSIPPI

TABLE 1

Analyses

Parts per million

PLACE	SiO_2	Fe	Ca	Mg	CO_3	Cl	NO_3	SO_4	COLOR	TURBIDITY
Gulfport	1.4	0.2	12.8	9.7	133	4.6	2.9	8.0	0	0
Biloxi	7.0	0.0	0.0	6.0	112	55	0.0	11.1	0	0
Ocean Springs	39	0.6	0.0	1.0	130	93	0.0	19.2	0	0
Pascagoula	23	6.8	0.0	2.0	183	430	1.8	65	30	0

Hypothetical combinations

Parts per million

PLACE	$MgCO_3$	$CaCO_3$	Na_2CO_3	Na_2SO_4	NaCl	$NaNO_3$
Gulfport	33.3	31.5	153.7	11.3	7.0	3.0
Biloxi	2.0	0.0	171.0	16.3	90.0	0.0
Ocean Springs	3.3	0.0	224.0	28.3	153.0	0.0
Pascagoula	7.0	0.0	314.0	95.0	709.0	1.7

able of being drawn from water bearing strata, hundreds of feet thick and having outcrop of thousands of square miles is very great. The problem is one concerning number and arrangement of wells.

Figure 1 shows an artesian well at Gulf Hills, Mississippi. This

FIG. 2. WELL AT GULFPORT, MISSISSIPPI

well was bored to a depth of about 800 feet. It produces about 350 gallons of water per minute.

Figure 2 is a photograph of a well brought in near Gulfport that gives a constant flow of nearly a million gallons a day.

Quite a common sight in the coastal region is shown in figure 3. The wells in this section vary from 500 to 1400 feet in depth. The pressure is sufficient to carry the water to the second floor of the buildings. All the families living in the country are supplied with water

FIG. 3. TYPICAL FLOWING WELL AT OCEAN SPRINGS, MISSISSIPPI

from private wells and many city residents have their private artesian wells. The system used in the cities is the storage of water in large service concrete reservoirs, the water being pumped to the

consumers from these containers. Gulfport is supplied in this way from some 8 or 10 wells.

The analyses of some artesian waters are shown in table 1. The samples analyzed represent the water supplied by the city to the consumers. Small population centers as Pass Christian, Mississippi City and Long Beach have no municipal supply. People in these settlements are furnished by private wells.

TABLE 2

I SYSTEMS OF DISTRIBUTING BASES AND ACIDS	II ANALYSIS, PARTS PER MILLION	III CALCULATION OF REACTING VALUE PARTS PER M × R	IV REACTING VALUE
Mg to CO_3	9.7	9.7 × 0.0822	0.79
Ca to CO_3	12.8	12.8 × 0.0499	0.63
Excess CO_3 to Na	133	133 × 0.0333	4.32
SO_4 to Na	8.0	8.0 × 0.0208	0.16
Cl to Na	4.6	4.6 × 0.0282	0.12
NO_3 to Na	2.9	2.9 × 0.0161	0.04

V DISTRIBUTION OF REACTING VALUES	VI CALCULATION OF PARTS PER MILLION	VII PARTS PER MILLION, HYPOTHETICAL COMBINATION
0.79 as $MgCO_3$	0.79 × 42.2	$MgCO_3$ = 33.3
0.63 as $CaCO_3$	0.63 × 50.0	$CaCO_3$ = 31.5
4.32 − 1.42 = 2.90 as Na_2CO_3 2.90 × 53		Na_2CO_3 = 153.7
0.16 as Na_2SO_4	0.16 × 71	Na_2SO_4 = 11.3
0.12 as NaCl	0.12 × 58.5	NaCl = 7.0
0.04 as $NaNO_3$	0.04 × 85	$NaNO_3$ = 3.0

CALCULATION

The scheme for calculating the hypothetical combinations from the reacting values is that used by Foulk.[7] This is illustrated in table 2 with the Gulfport analysis.

For calculating (*r*) the reacting coefficient and the factor in column VI see Geological Survey of Ohio Bulletins 29, pages 33–36.

DISCUSSION AND CONCLUSION

Water is supplied the Illinois Central locomotives at Gulfport from a well approximately 500 feet deep. Downs[8] states "it is remarkably

[7] Geological Survey of Ohio, Bullein 29, page 36, 1925.

[8] President, Illinois Central System, personal communication.

free from scale forming substances and does not cause corrosion. The non-incrusting solids are rather high, as a result the water has a tendency to foam. We experience but little trouble from this cause." Knowles[9] states "that the waters of the southern lines of the Illinois Central are with few exceptions among the best boiler waters of the country."

Water is supplied the Louisville and Nashville Railroad Company from a well at Ocean Springs. None of the waters are treated before delivery to the tanks of the locomotives and no boiler compounds are used. Cole[10] states "they have experienced no difficulty in pitting, but are troubled some with foaming which condition is successfully overcome by blowouts."

The artesian waters of the Mississippi coast if classified would be placed in the category of foaming waters, because of the sodium salt content which is conducive to foaming. Such waters in the presence of certain types of finely divided solid particles will foam.

Because of the high concentration of Na_2CO_3 the waters may cause some embrittlement due to the formation of NaOH. Such troubles, however, are successfully overcome as mentioned above.

Generally speaking it may be said that the artesian water of the Gulf Coast is good for all purposes. The problem for the water works engineer is one of well distribution and means of storing and placing the water at the consumer's convenient disposal.

[9] Jour. Amer. Water Works Assoc., vol. 16, July, 1926.

[10] President, Louisville & Nashville Railroad, personal communication.

FILTRATION IMPROVEMENTS AND ECONOMICS WITH PRECHLORINATION[1]

By J. S. Whitener[2]

Water works men as a whole are just beginning to realize the advantages and reap some of the benefits of prechlorination. In this state, all filtered surface water supplies and some well supplies are chlorinated for ordinary bacterial destruction. This chlorination acts as a factor of safety or secondary line of defense for surface supplies and as a precautionary measure for well supplies.

In most of our plants, the chlorine is introduced into the filtered water as it goes from the filters to the clear water reservoir. So far, little if any chlorine has been introduced into the raw or coagulated water. This paper deals with the chlorination of raw and coagulated water, particularly the latter.

CHLORINATION OF RAW WATER

The writer chlorinated the raw water at the Raleigh (North Carolina) plant with the idea of killing cyclops, sometimes called "water fleas," which were very numerous in the water and at times, together with other organisms, so clogged the filters that they would run only from ten to fifteen hours.

Chlorine was introduced at various times depending on the turbidity of the water. Turbidity ranged from 10 to 200 p.p.m. and the chlorine dosage from 0.2 to 0.5 p.p.m. A higher dosage was not used as the writer did not wish to use very much more chlorine than was being used in the filtered water. During the time that prechlorination was tried, very little chlorine was needed in the filtered water as the chlorine demand had already been taken care of. Very good ortho-tolidine tests were obtained in the mixing chamber, varying from medium lemon yellow to slightly orange.

Due to the fact that cyclops would have to be killed and retained in

[1] Presented before the North Carolina Section meeting, November 9, 1927.

[2] Superintendent of Filtration, Water Department, Raleigh, N. C.

the coagulation basin inside of four hours in order to keep them off the filters and as they were observed to live in test tubes of raw chlorinated water and on top of the filters for twenty-four hours or more, prechlorination was of no help in this respect. No saving in chemicals or wash water was obtained, so the writer abandoned prechlorination of raw water.

CHLORINATION OF COAGULATED WATER

The writer first introduced chlorine into the coagulated water for the purpose of sterilizing the filters. The filtered water samples had been showing gas in lactose broth, but very few were confirmed as B. coli. The filters might have become seeded with B. coli and it was to eliminate this possibility that chlorine was introduced into the coagulated water just before it entered the filters.

Before chlorination, the filter runs had averaged about twenty-five hours and at that particular time the water in the clear water reservoir had a light green cloudy appearance, with a depth of visibility around the edges of about 5 feet. Raw water turbidity was 300 and coagulated water turbidity was 5 p.p.m.

Chlorination was started one afternoon and the next morning the clear water reservoir was absolutely clear. As this reservoir empties itself about twice a day and as it had never been known to clear up in less than two days, a clear sparkling effluent is the first advantage charged to prechlorination. In order to check this result, the chlorine was stopped for two days and then started again. During the two days that chlorine was not introduced, the water in the reservoir immediately became cloudy. Since the chemical dosage and character of the raw water remained the same, it was assumed that the chlorine was responsible for the clearing up of the water.

After prechlorination, samples of filtered water, tested for B. coli in lactose broth, showed no gas. This meant that either all B. coli were killed before going on the filters or that the filter was helped to such an extent that it was able to remove all of them.

Before chlorination, the surfaces of the sand beds were covered with large cracks, some of them 2 to 3 inches in width. Since prechlorination, all these cracks have disappeared and the sand beds are covered with an absolutely unbroken mat.

Following prechlorination, the filter runs increased from an average of twenty-five to eighty hours in a week's time. These long filter

runs continued until the yearly migration of cyclops took place. In the fall of the year, the raw water has a very low turbidity and cyclops come down from the lake in the raw water in countless numbers. The chlorine, of course, will not kill these cyclops and as they will not settle out in the coagulation basin, they come in on top of the filters and clog them up, thereby decreasing the filter runs to about twenty hours. The elimination of cyclops is another problem and will not be discussed in this paper.

In summary, the writer wishes to say that at the Raleigh plant, chlorination of the coagulated water has eliminated all fermentation in lactose broth of filtered water samples; caused the filters to produce a clear, sparkling effluent at all times; caused all cracks to disappear from the tops of the filter beds; and, excepting when cyclops are exceedingly numerous in the water, the filter runs, during periods of high raw water turbidity, have been doubled and during periods of low raw water turbidity, have been increased by one third.

The above results have been noted since prechlorination of the coagulated water was started on September 1, 1927. Due to the short length of time, they are by no means conclusive. But the writer can safely say that, without using any more chlorine than formerly, the Raleigh plant has produced clear, sparkling water at all times at less cost, due to chlorination of coagulated water.

DISCUSSION

MR. G. D. NORCOM:[3] Mr. Whitener mentioned the fact that he had a very low residual turbidity left after the water had passed through the basin. I think he said 5 parts per million. It just occurred to me that it might be possible that, with the removal of the greater part of the turbidity, the chlorine might have the effect of coagulating that last residual turbidity which is extremely low.

I cannot say why it should do that, but if that took place it would go a long way toward explaining the fact that he got a sparkling effluent where before he had an opalescent effluent and, incidentally, might explain the fact that the condition of the surface of his bed improved after the treatment.

[3] Superintendent of Filtration, Water Department, Charlotte, N. C.

RED WATER AT SOUTHERN PINES, NORTH CAROLINA[1]

By C. O. Butler[2]

Our troubles with red water at Southern Pines began in the fall of 1925. Up until that time the town supply had been taken from a group of springs which fed into a small reservoir. This water was treated with alum and lime, and filtered immediately with no allowance for coagulation and subsidence. The old plant had been in operation for a number of years and was handled by untrained labor. In 1924 it was evident that the old plant was not only obsolete, but also insufficient to meet the demands of the town. Therefore construction was started on a filter and pumping plant of modern design and full equipment. The new plant has a normal capacity of a million gallons daily. The raw water is taken from a 60-acre impounding reservoir, which was not stripped of undergrowth when built. This water as it enters the reservoir is similar in quality to the supply at the old plant, very soft, of low alkalinity, and low in all minerals. From the quality of the water no trouble was anticipated. The new plant was opened in the late summer of 1925. The first water delivered carried the tastes and odors of the new material, as would be expected, but the disagreeable taste and color persisted. Soon the black color changed to a red and in the winter much trouble developed with red water. In January, 1926, the town water board secured the service of a trained man, L. L. Hedgepeth, now at Elizabeth City, who took charge of the plant the following month.

The first thing Mr. Hedgepeth found was that the raw water could be coagulated only at pH of 5.2 to 5.4. This left the filtered water in highly acid and corrosive condition, and no after treatment was being used to correct the pH. Analysis of the water showed the red precipitate to be practically all iron. He immediately began the use of sodium carbonate as a temporary remedy until a machine for feeding lime could be installed. The pH was run up to the neutral

[1] Presented before the North Carolina Section meeting, November 9, 1927.

[2] Superintendent Water Department, Southern Pines, N. C.

point, which caused the iron in solution in the mains to precipitate. This was flushed out thoroughly, then periodic flushing kept the trouble down to a certain extent. Through the summer of 1926 the pH was held from 6.6 to 7.0, and no annoyance came from red water. However, considerable complaint came from odors which seemed to develop during coagulation and settling. To remove these odors we installed an aeration system, which sprays our filtered water onto the roof of the clear water well. This aeration raises the pH nearly to the neutral point itself, but also increases the dissolved oxygen content of the water which is an aid to corrosion in the mains. The slight increase of oxygen is not enough to unbalance the benefits derived from the removal of odors.

The red water began to appear again last fall about November. The consumption was increasing at that time due to the influx of tourists into the community. With the first cold period the water commenced to turn red. During the past winter the pH was held quite near 7.0. By periodic flushing the trouble was held under better control than during the previous winter. The color began to clear about April and since June has disappeared. The latter part of June the dissolved iron content in the mains ran as high as 0.7 p.p.m. at the ends of some of the longer mains, while at the storage tanks it ran only about 0.15 to 0.2 p.p.m. We kept the treatment of the lime at the same point through the summer until Mr. Catlett suggested a higher lime treatment in an effort to secure a protective lime coating in the pipes. The marble test was used to determine the pH at which the CO_2 would be neutralized by the lime. We find it to be about 8.4 to 8.6. We then ran our lime up so the effluent from the pumps shows a pH of about 8.8 to 9.0. The alkalinity, using phenolphthalein as indicator, runs from 1 to 3 p.p.m., preferably not over 2. An alkaline taste is noted in town when the alkalinity exceeds 3 to 4 parts. No trouble has been encountered since increasing the pH, and the dissolved iron in samples taken from the distribution system runs from 0.2 to 0.4 p.p.m. This amount will give us no trouble with color. We can see the formation of the lime coating in two services at the sewage disposal plant about a mile from the filter plant. The inside of these service lines has a very good coat of lime at present.

We have two hypothesis as to the cause of our troubles. The first to suggest itself is that the water as it leaves the plant is of a corrosive nature, due probably to organic acids from decaying organic

matter left in the impounding reservoir. If this be the cause the lime coating should stop the corrosive action at present, and in several years as the organic matter is dissolved out and is washed from the reservoir the acidity and corrosiveness of the raw water should become much less than now, and thereby remove the cause of the red water. If this be the case, however, it appears that the solution of the iron should go on more rapidly during the summer when the temperature of the water is higher and the contact period is greater, due to minimum consumption.

The facts show that this is not the case. The red water shows up with the cold weather and increased consumption. This would tend to prove that the corrosive action is over, and that we are washing out the sludge that was formed during the preceding years. Some of this sludge in the pipes consists of aluminum compounds precipitated in the mains after filtration due to inefficient or insufficient coagulation, as was the condition in the old plant. If this is the case the lime coating will tend to harden the precipitate and hold it in the pipes until we can give them a thorough cleaning, after which we anticipate but slight trouble.

DISCUSSION

Mr. Maurice Le Bosquet, Jr.:[3] When the new filter plant was first placed in operation, conditions were so serious that the water was almost undrinkable. At that time, Mr. L. L. Hedgepeth was called in as Superintendent of Water Works on the recommendation of the State Board of Health. Mr. Hedgepeth was able, by the institution of chemical control, after treatment with lime, the installation of an aerator and the inauguration of a system of frequent flushing of the mains, to eliminate practically all of the trouble. Conditions were satisfactory for a time, but in December, 1926, the trouble returned. At the time of the investigation, the "red water" trouble was not nearly so serious as it had been, but the trouble existed to some extent and the town authorities felt that they should do everything possible toward its elimination.

The investigation indicated that the public water supply of Southern Pines was almost pure from a chemical criterion, extremely soft, very low in dissolved solids, low in carbon dioxide, and contained practically no iron in the water as it was delivered to the force main

[3] Of Morris Knowles, Incorporated, Consulting Engineer, Pittsburgh, Pa.

to town. It was concluded that the corrosiveness of the water, as delivered to the distribution system, was due to its very low mineral content and the fact that it was well saturated with oxygen and thus chemically active on metals. Its low alkalinity and freedom from alkaline salts prevented the formation of any deposit or protective coating upon the pipe which might have prevented corrosion.

In an effort to determine a treatment of the water that could be applied at the filter plant so as to prevent corrosion, the following correction possibilities were investigated.

1. Aftertreatment with lime.
2. Aftertreatment with soda ash.
3. Aftertreatment with caustic soda.
4. Coagulation with sodium aluminate and alum.
5. Coagulation with lime and iron sulphate.
6. Aftertreatment with sodium silicate.
7. Pretreatment with calcium chloride and aftertreatment with sodium silicate.
8. Aftertreatment with sodium silicate and lime.

The treatments that offered the greatest possibilities were aftertreatment with lime and aftertreatment with sodium silicate alone, in combination with lime, or following pretreatment with calcium chloride.

In investigating the effect of the various treatments on the corrosiveness of water, the water was placed over iron filings and the appearance of the filings after standing twenty-four hours was taken as a criterion of the corrosiveness. On samples containing considerable carbon dioxide, this method did not give dependable results unless a correction was made for the amount of iron that went into solution. However, the water under consideration contained very little carbon dioxide and this factor had little effect on the results in practically all cases. All tests for corrosiveness were considered comparative only, comparison being made with water from the Southern Pines old supply and the Pinehurst supply, both waters being known to give very little trouble due to corrosion.

TREATMENT WITH LIME

Lime was added to the filtered water so that the hydrogen ion concentration was adjusted from pH 6.2 to 8.4. The results of this test showed that the corrosiveness of the water was unchanged by a change in the hydrogen ion concentration over the range used. Con-

sequently, larger quantities of lime were added and it was found that a dose of 17 p.p.m. of lime would reduce the corrosiveness of the water to a point where it would not cause trouble. The hydrogen ion concentration of the water when treated with this dose was above pH 9.8, the limit of the indicators on hand. The alkalinity of the water treated with this dose was 21 p.p.m. and there was 1 p.p.m. of hydroxyl alkalinity present.

The hydrogen ion concentration of the water, after being placed over calcium carbonate, was found to be pH 8.4 and it was expected that a reduction in the corrosiveness of water would be obtained at this point. Indications obtained were to the contrary.

It was realized that conditions during the making of these tests for corrosiveness did not correspond to actual conditions in the water mains, but the indications were that a rather high lime dose would be necessary to be effective.

TREATMENT WITH SODIUM SILICATE

Inasmuch as the investigation at Southern Pines had lasted over a considerable period, it was thought best to conduct tests on the effect of sodium silicate in the laboratory at Pittsburgh. In corroboration, tests were also made by Robert Spurr Weston of Boston, at the request of our organization. In these investigations, the corrosiveness of the water was measured by placing steel wire in the water and noting the appearance of the wire and determining the dissolved iron in the water after twenty-four hours.

The results of the tests with sodium silicate indicated that, while considerable improvement was possible by the use of sodium silicate alone, better results could be obtained for the money expended if sodium silicate and lime were used, both being added as an aftertreatment or sodium silicate and calcium chloride were used, the calcium chloride being added as a pretreatment and the sodium silicate as an aftertreatment.

The best doses in the use of sodium silicate and calcium chloride appeared to be equal parts of calcium chloride added before cogulation and sodium silicate added to the filter effluent. Ten parts per million of each chemical gave good results. The best doses with sodium silicate and lime appeared to be 10 p.p.m. of sodium silicate and 5 p.p.m. of lime, both chemicals being fed into the filter effluent.

CONCLUSIONS

As a result of the investigation, it was concluded that sodium silicate and lime was the best combination of chemicals to use. The use of calcium chloride as a pretreatment in place of the lime aftertreatment would be preferable, but inasmuch as facilities were already available for adding lime, it was felt that this advantage would offset any disadvantages, at least until satisfactory results were found to be possible by the use of the silicate.

It was thought that the use of lime alone in rather large doses, although lower in cost, would not be as satisfactory as sodium silicate used with smaller doses of lime or calcium chloride for the following reasons:

1. Lime alone, with high doses, would increase the hardness of the water more than the smaller doses used with sodium silicate.
2. It was felt that the high pH of the water delivered when rather high lime doses are used would be objectionable.
3. The general opinion of workers on the question of corrosion is that the formation of a calcium carbonate coating is not feasible in waters of very low alkalinity, such as that at Southern Pines.
4. The addition of lime would necessarily have to be a continuous process carefully controlled.

The advantages of sodium silicate were that it would not increase the hardness of the water and that it would deposit the coating less likely to be affected by any irregularity of the dosage. It was thought that the cost would not be excessive, inasmuch as the dosage could be reduced somewhat after the coating had been once established.

One of the most significant conclusions, as expressed in our report to the town of Southern Pines, is as follows:

> The investigation thus far has been conducted entirely on a laboratory scale. The results obtained are valuable chiefly as a guide in conducting tests at the filter plant itself and interpreting the results from such tests. Such plant tests should be made under the direct supervision of a trained chemist, in accordance with instructions appended.

We realized that only an indication could be obtained by conducting an investigation on a laboratory scale and that the ultimate solution would rest upon the results obtained at the plant itself. It is believed that the results of the investigation on a laboratory scale will give valuable information in determining what possibilities are

not worth trying and in giving an idea of what the proper doses of the chemicals should be.

MR. G. F. CATLETT:[4] Mr. Le Bosquet's figures are very interesting. However, there are one or two observations I would like to make in respect to his conclusions.

His results were largely derived from laboratory tests. A laboratory test to determine the corrosion or the prevention of corrosion of cast iron pipes, as it occurs, is very difficult to devise. I have investigated and experimented to quite an extent, myself, trying to get some method that would serve as a test of the corrosibility or the preventive action against corrosion of a given water. Baylis of Baltimore has done considerable work along this line with test plates, etc. Messrs. True, Hedgepeth and some of our other North Carolina operators have done considerable work with the non-filing method. The result of these efforts force us to the conclusion that there has been devised no method so far in the laboratory with which you can determine whether a water will cause red water trouble in the mains or not, or even the comparative corrosibility or comparative action along that line between several waters.

Active plant and distribution system results seem to be the only reliable criterion. However, we have used one test to control the corrosibility of the water, which Baylis had used at Baltimore, the determination of the dissolved iron in the water after it has passed through the distribution system.

The confusion, I think, is from the old idea that corrosion was caused by acid action on the iron itself. That hypothesis has pretty well been disproven. Instead of having a corrosion of the iron when you have red water, you have a removal of the coating which prevents corrosion of the iron. When you take a lot of iron filings and try to get a coating on that with the immense surface area exposed by the filings and the sharp corners and the rubbing between, you cannot simulate the condition of the pipe scale in the pipes over which the water is flowing rather quietly.

The first good results, I might say, were obtained at Fayetteville. They have a red water trouble there very similar to Southern Pines' water. Last spring, a year ago, they had an awful plague of red water. The whole town was up in arms against the water superintendent as a result of the water he was delivering to them, and he

[4] State Board of Health, Raleigh, N. C.

asked the State Board of Health to coöperate with him in relieving the situation. Secondary lime treatment was tried and the trouble was very much relieved and in fact disappeared.

We thought then that the problem was solved as all during the summer months there were no complaints, and also during the fall and winter.

Last April, without any warning whatever the red water trouble came again in an intensive way. The water department office was swamped with complaints, and did not know what to do.

It was logical to suppose that, although the adjustment of secondary lime had relieved the situation, there was a recurrence of the trouble which the lime prevented in a more intense way. So we applied this marble test that Mr. Butler referred to in his paper, and found that the filtered water at Fayetteville reached an equilibrium at 8.8. We then took the bull by the horns and carried the lime up above that to 9.5. Almost immediately the red water disappeared, and since last April it has continued to be non-existent. Mr. Weathers says that it not only corrected that trouble but they have been having the best water that Fayetteville has had since he has been superintendent. It is the first time since his connection with the Fayetteville water department that he has been able in his own home to draw a bath-tub full of hot water as white and as clear as the cold water.

Mr. Shell, the plant superintendent at Fayetteville, started in April and adopted this marble test as a routine. Every few days he runs his marble test and records the result. He finds that the equilibrium point varies, that it is sometimes as high as 8.8—I think that is the highest he has had—and goes down as low as 7.6. The variation seems to be more or less seasonal, which rather corroborates the first theory that at certain seasons of the year when the red water occurred the CO_2 or possibly some other organic acids in the water went up to a maximum, and when it went to that maximum it needed higher doses of lime. But the Fayetteville plant is now running on that principle. We want to wait until we pass another spring, which has been the season of maximum trouble.

The same principle I think applies at Southern Pines, although the time of their usual trouble is the early fall. They have gotten by so far without that trouble, and the people are well pleased with the water.

My idea in connection with the whole matter is that if lime will

correct the trouble, there is no use in experimenting with the more expensive chemicals, such as sodium silicate, the application of which has not been entirely worked out and is rather complicated.

MR. G. D. NORCOM:[5] From our experiences on red water trouble, I believe we can pretty nearly come to the conclusion that, with the alkalinity we have to deal with in North Carolina, when the waters are alum treated it is almost a certainty that some red water trouble will develop. It seems equally certain that red water trouble may be reduced by secondary lime treatment.

Charlotte has been running for some time without the use of secondary lime. The raw water at Charlotte is easily treated and easy to coagulate. As a rule it does not require very heavy doses, the doses running from only 0.3 to possibly 0.7 grain per gallon as a maximum. That treatment only reduces the pH about two or three tenths.

However, during the past summer, the red water trouble has been aggravated a little bit at Charlotte, owing to the fact that the water has had a higher turbidity than in the past, and we have been forced to feed a little more alum. That is one reason.

The next reason is that we believe that the mains had a coating of lime in them when the new plant was put in, due to the fact that with the old filtration plant alum and lime were added simultaneously, and the lime was frequently in excess. Both Mr. McConnell and I believe that there was quite a residual coating of carbonate of lime on the pipes when the new plant was put into service, and probably that has gradually been dissolved out.

At any rate, for one or both of those reasons—and perhaps others—the trouble became so intense this summer that frequent blowing of hydrants was necessary, and we were wasting so much water that it appeared that the time had come when we had best take some steps to correct it. We have now installed a secondary lime treatment. While it has been running only two weeks, the indications are that we are very materially checking that red water trouble. We are only using about 35 pounds per million gallons there, or about 4 p.p.m. of lime, which is absolutely negligible. When you consider a total hardness of 18 or 20, an increase of 3 or 4 p.p.m., when you convey it to grains per gallon, is pretty small. That raises the pH from about 7.6 to 8.0 and we may have to go to a little higher.

[5] Superintendent of Filtration, Water Department, Charlotte, N. C.

There is just one interesting point which Mr. Le Bosquet might be interested in, and that is that the raw water at Charlotte contains from 10 to 15 p.p.m. of soluble of SiO_2 after filtration. That is a little bit high for clear sparkling water after filtration. It just raises the possibility that we are really using a combination of silicate lime treatment there, that is, the silicate being already present and the lime added on.

MR. A. O. TRUE:[6] The question of taste is an important one. We would have to be a little careful in lime treatment, about getting caustic alkalinity. I do not know that we know very much yet about the effect of caustic alkalinity upon the human system.

I recollect that some years ago at certain plants which had to use lime, not for secondary treatment but for coagulation, owing to the vast changes in the water, it was difficult to follow consistently the proper treatment, with the result that at times an excess of lime was added, giving quite a considerable caustic alkalinity. And I know at that time it was considered by those who were experts on the question that that was quite objectionable. I should like to hear something more on the question of caustic alkalinity. Of course, if it causes a bitter taste in the water, that, in itself, would be objectionable. But I would like to hear from somebody as to what the effect of caustic alkalinity might have on the system, what is the medical and the biological view on that thing.

MR. CATLETT:[4] In adjusting the pH of lime to 9.5 at Fayetteville, a rather high dosage, we were fearful of that very thing. We watched the distribution system very closely at the time this high application was made and called the attention of the local officials to that danger and asked them to watch for it. In addition to that, we sent our men down from Raleigh on trips, especially for the purpose, to go over the distribution system with the superintendent. They looked for any indication of tastes or any other objectionable changes in the water caused by this higher treatment. No one has been able to report any trouble, nor has the superintendent had any complaints from any of the consumers.

Tastes and odors are rather elusive things, and where a water has from time to time more or less tastes and odors, I think people usually ascribe them to almost any reason that happens to come up.

[6] Sanitary Engineer, Proximity Manufacturing Co., Greensboro, N. C.

However, to go further into the matter, I made a special investigation of all the literature and information I could find on the effect of caustic alkalinity. North Carolina has no softening plants. Some of the other states have to soften and they use a softening treatment. Columbus, Ohio, under Mr. Hoover, is one of the outstanding filter plants where they have a very heavy pollution and a softening process also. I find in Mr. Hoover's reports that frequently he has to adjust his water for reasons which he specifies to a caustic alkalinity as high as 15, and sometimes 20. I find that the St. Louis water is adjusted to a similarly high caustic alkalinity. Whether there are any complaints from the people of Columbus or St. Louis, I have no information, but I presume that they are satisfied with the water treated that way. Those figures are really much higher than the Fayetteville water was raised by adjusting the lime to 9.5 pH. The caustic alkalinity there went as high as 8 or 10. We concluded after that observation at Fayetteville that we need not fear bad results in the high treatment.

One water acts differently from another, and I am not entirely satisfied. I do not mean to state that that is conclusive. It may give some trouble in other waters. But we are watching for it and only time will determine whether we are going to have any trouble along that line.

MR. F. H. WARING:[7] The gentleman has raised a question about Columbus and other plants which may have used caustic treatment. I do not like to take the time of this meeting to discuss the conditions in my own state, but as long as you have raised that point I should be glad to give you some of our experiences along that line.

The plant at Columbus, Ohio, has been operating on a caustic lime basis since 1908. The experience of almost twenty years in its treatment indicates that there are no harmful effects from the medical viewpoint; that is, in the treatment of between 5 to 15 p.p.m. causticity. It is not detrimental to the physical well-being of the consumer.

The matter of taste, however, is an item which you have to watch. If you get up to 20 or 30 p.p.m. causticity, you will taste it. Some people will describe it as a limey or a flat taste; and, as such, it is objectionable.

Of course, in the Columbus plant, the high treatment in lime is

[7] Chief Engineer, State Board of Health, Columbus, Ohio.

for the purpose of water softening. The reactions in softening will not take place to best advantage until high causticities are reached.

Up until the last five years it was not practicable to carry the causticities much above 10 or 15 parts, only on account of the taste factor. In the last few years at several other Ohio plants, we have been using carbon dioxide to convert the causticity into bicarbonate alkalinity, with the result that the taste factor is eliminated and the causticity is eliminated. I doubt if any of you gentlemen could tell the difference between the taste of a water softened by the excess causticity method supplemented by carbon dioxide, from any other natural water of the same hardness.

The medical fraternity at Columbus have been exercised in times past over the use of the lime. They have wondered about it. Mr. Hoover could tell you of an experience he had with his own physician. One day the physician was called to treat his small child, and in connection with his routine instructions said, "Boil the water." Mr. Hoover looked at him rather queerly and said, "Why do you ask me to have the water boiled?"

Then the physician recalled that he was in charge of the city water works, and he said, "Oh, I didn't mean to infer that the water was not safe, but those are our usual instructions." And then he said, "Well, if you boil the water, you know you precipitate the salts of calcium."

Mr. Hoover called his attention immediately to the fact that he had prescribed for the baby a certain amount of water and of milk, with an addition of lime water. He made a rapid calculation and said, "Doctor, do you know that you are asking me to give my baby an amount of lime which is about five times the amount of lime that that baby would get in drinking as much water as I drink every day?"

The physician was stumped. The fact remains that the milk fed to the baby and treated with lime water carries more than 50 times the amount of calcium contained in any similar portion of water softened with lime to an excess.

As to another feature in the water softening—and, presumably, in the lime treatment which you may want to undertake to correct the corrosive troubles—if you carry the lime treatment to the point of causticity and do not recarbonate at all, you may experience some plant difficulties in the way of incrustation. The experience of previous years in softening works when they filtered caustic water has been that the sand grains grow, the gravel grows, the under-drains

and perhaps the meters become incrusted. For this reason carbon dioxide has been introduced as a secondary process in all of the water softening plants in Ohio. There are some 21 water softening plants. Practically all of them in the last 7 years have incorporated the carbon dioxide process.

There is also one new feature in softening. It was discussed last week in the Ohio Conference on Water Purification—namely the carrying of the caustic treatment to an excess away over what it was heretofore deemed advisable to carry it.

I speak now with reference to two new plants, Piqua and Greenville, Ohio, where the treatment is carried regularly between 40 and 70 p.p.m. caustic alkalinity. Of course, that caustic alkalinity is destroyed by carbon dioxide before filtration.

The accomplishment in softening is remarkable. What we knew in the early days of softening was that the mass reaction of the chemicals which is obtained when you add all the chemicals to a portion of the water, is repeated on a large scale in the entire volume of water treated. The Piqua and Greenville works, where they carry this lime treatment to that degree, accomplish a complete removal of the magnesium. Magnesium will not come out unless you add lime to a large excess above the ordinary amount. The treatment at those two plants, accomplishing the removal of all the magnesium, throws it down as magnesium hydrate. It is a fluffy, flocculent precipitate. That very precipitate makes possible a reduction in coagulant. The treatment at Greenville, Ohio, is now 19 grains per gallon of lime, 0.4 of a grain of soda, no alum, on a water of hardness to start with 450, and with a finished product of less than 90 parts per million.

The extra lime treatment made possible by the carbon dioxide has accomplished an additional softening of over 30 p.p.m. and a reduction in chemical cost due to the reduction in soda and the elimination of coagulant.

As to the possible ill effects of caustic alkalinity as such, I will summarize by saying that with from 0 to 15 p.p.m. causticity no fear may be had as to the physiological effects. Taste will not be encountered unless you leave in the final water a residual causticity of more than 15 p.p.m. If you follow with carbon dioxide treatment, you can overcome any such criticisms.

MR. NORCOM:[5] I believe in those plants where they use excessive causticity it is unnecessary to use chlorine for bacterial removal.

It may be possible that a combination of chlorine and causticity—and I took this from a remark made by Mr. Enslow—might produce a calcium hypochlorite or some other hypochlorite which would have a taste and might be noticeable with only a causticity of a few parts per million.

MR. F. H. WARING:[7] In an answer to that inquiry, Columbus has chlorinated the effluent for the last eight years. They are using liquid chlorine today.

My statements with regard to the use of chlorine apply to the caustic water. The only reason for adding chlorine at the Columbus plant has been to satisfy certain of the medical profession who did not know the bactericidal effect of lime and insisted upon some factor of safety. So Mr. Hoover put in chlorine. Now he uses as high as 0.5 p.p.m. of chlorine. We ran experiments to determine what would be the effect of the loss of the chlorine or the loss of its efficiency.

Of course, as the lime treatment was correct he had no chance of finding out what might be the bactericidal effect of the chlorine so applied. But possibly one or two days in the year when the floods were on, and due to some faulty operation of his operator, he was hoping that there would be a chance for a demonstration. Such a chance occurred, although he did not want it to occur then. It occurred one night last year, when the water coming into the filters was not quite caustic, and therefore was not sterile. The chlorine did have its effect, which was desired, and the finished product was everything that it should be.

As to the creation of taste due to the chlorine, there has been no such taste encountered in the seven or eight years when chlorine has been used at the Columbus plant. The caustic alkalinity varies between 5 and 15 p.p.m.

COMMENTS ON MANUAL OF WATER WORKS PRACTICE (NEW ENGLAND WATER WORKS ASSOCIATION, FEBRUARY 8, 1928)

Allocation of Streams for Municipal Water Supply

By Caleb Mills Saville[1]

Chapter II of the Manual "Water Works Practice" issued by the American Water Works Association, begins by stating "The need for allocation arises when two or more users compete for the same water or for the channel of a stream."

In the past, this need has raised many perplexing questions for law and practice between individuals, states and nations.

The basic principle of civilization is the necessity for individuals, states and nations to dwell together in harmony, and law, in its last analysis, is but a means to that end. Common and statute law regulate use of water courses between individuals of a state or nation and internation law, so-called, regulates or at least indicates procedure between separate states or nations.

For controversies between individuals of the same state, the courts of law of the state provide redress or at least decide between conflicting claims. Between nations, treaty or war settles disputes.

In the United States, a complex situation arises because the states are separate sovereignties, except so far as they delegated their powers to a federal government by ratification of the Constitution of the United States.

For individuals in the same state, the old English doctrine of riparian rights holds, except so far as statute law or easement acquired by prescription has intervened.

It is said that necessity knows no law, which is but another way of saying that those things which are essential to life take precedence over those matters which are of lesser importance. What may be the distinction in gradation from a necessity of life to a desirability of pleasure, is a matter for dispute and argument to be settled by

[1] Manager and Chief Engineer, Hartford Water Works, Hartford, Conn.

compromise or court authority in this country. The several states of the United States of America have developed procedures governing the allocation of water rights within their several domains, and an outline of this procedure is given on pages 38 to 40 of the present Manual, immediately followed by an admirable discussion by groups of states.

The growth of population and its demands for the necessities of life as well as means of support and enjoyment of comfort, has increased the demand for that element upon which life itself is most dependent—water.

The only source of water is from precipitation in the form of rain or snow. The amount falling in any particular locality is fixed within certain rather narrow limits, and of this amount natural agencies as topography and climate make it impracticable, if not impossible, to retain a large proportion for human use. Within the state therefore, some competent authority must decide what portions of water possible for human use shall be allocated for different uses.

As the states or localities are sparsely inhabited, less attention need be given to the uses to which water is put, other than for preservation of human life, but in those states and districts that are more thickly settled or where, from natural conditions, water is scarce, the state, which represents all of the people, must step in and allocate the water supply for the greater good of the greatest number.

Streams of water often do not follow the political boundaries of cities or states, and as states themselves are only individuals of a nation, it seems to follow logically that some authority should be available to settle disputes as to use of water running therein.

The power and authority of the Federal Government as regards interstate streams, is expressly limited to regulation for the purpose of navigation. The Supreme Court of the United States has stated that a state "can impose its own legislation on no one of the others and is bound to yield its own views to none,"[2] but in the same case, the Court held that the respective states were each entitled to an equitable portion of the waters of a common river, the extent of use in each state being determined by facts and circumstances. In another case,[3] the Court recommended settlement of the controversy by interstate compact.

The power to make treaties or compacts between states, as stated

[2] Kansas vs. Colorado (206 U. S. 46, 87–97).

[3] Washington vs. Oregon (214 U. S. 205, 218).

in Section 10, Article I of the Constitution of the United States is: "No State shall, without the consent of Congress . . . . enter into any Agreement or Compact with another State."

In the case of Kansas vs. Colorado,[2] the Court also said "One cardinal rule, underlying all the relations of the States to each other, is that of equality of right."

From the past decisions of the Supreme Court of the United States, it seems clear that no state can say to another "I will" or "You shall not" to the vital injury of the other. If one state persists in doing that with an interstate water supply, which will cause irreparable injury to another, it seems probable that the Federal authority through its Courts, will, as it did in the Laramie River case, on the one hand, hold untenable that a state may use all of the water of an interstate stream which originates within its boundaries, and on the other hand, hold untenable the contention that appropriations of water should be limited to use in the watershed of the same river.

In the case of disputes between states over interstate water rights, there are two and only two means of interposition by the Federal Government:

1. The right of appeal to the U. S. Supreme Court (Article III Section 2 of the Constitution of the U. S.) "The Judicial Power shall extend to all cases in law and equity arising under this Constitution, the laws of the United States, and Treaties made, or which shall be made under their authority; to all controversies between two or more states; between a State and citizens of another State."

2. The right to regulate commerce and navigation between the states.

Under these limitations, it appears settled:[4]

1. That the authority of Federal control is limited by express constitutional reservation giving power to regulate commerce and is purely sovereign in its nature.

2. All other powers and interests, sovereign and proprietary, have passed to the states or to the subjects thereof.

3. Federal authority, legislative or judicial, cannot determine the rights between the state and the riparian owner—these are determined by state law.

It is an elementary proposition that nobody, whether sovereign or individual, owns the waters themselves of a running stream; their

[4] Limitations of Federal Control of Water Powers, Hon. Rome G. Brown, 62nd Congress, 2nd Session Senate, Document 20, 721.

use is all that can be claimed. As states are sovereign within their boundaries, there seems no other way but by compact between them, to settle a controversy, unless it can be shown that commerce (navigation) is affected.

The state also is circumscribed in its control, its title being limited:

1. To holding in trust for the specific purpose of navigation and allied public use.

2. Subject to private riparian rights as fixed by the law of the state.

The property rights of the private owner cannot be diminished by legislation, state or national.

In considering the limited rights which the Federal Government has over stream flow, the opinion of Chief Justice Taft, when Secretary of War, in the case of application of a riparian owner on the Des Plaines River, is illuminating. Secretary Taft said:

> Even if the Des Plaines River had been a navigable stream, and even if the application had been made and properly made to this department,—to say whether this would interfere with navigation if the department concluded it would not interfere with navigation, then it is not within the power of the department to withhold its expressing such an opinion and granting such a permit so far as the United States is concerned for the purpose of aiding the State in controlling the water power. . . . . All the United States does, assuming it to be a navigable stream, is merely to protect the navigation of the stream.

In the final analysis, the weight of law, such as it is, seems to favor exclusive use by a sovereign power of all the waters that rise or flow through that state. In the case of an International River (Rio Grande), the rights of the United States to all of the flow irrespective of uses in Mexico, was upheld by opinion of the Attorney-General (21 Ops. Atty-Gen. 274, 282) stating that "The fact that there is not enough water in the Rio Grande for the use of the inhabitants of both countries for irrigation purposes, does not give Mexico the right to subject the United States to the burden of arresting development and of denying to its inhabitants the use of a provision which nature has supplied entirely within its territory. The recognition of such a right is entirely inconsistent with the sovereignty of the United States over its natural domain," and in the case of the Colorado River, the same authority said "the United States has a perfect right to divert the waters of the Colorado River at any point above the international boundary with Mexico, irrespective of

the effect of such a diversion upon the flow of the river in Mexico or along that part of its course which forms the boundary between the two nations " (Op. of Atty-Gen. on Colorado River p. 58, Aug. 20, 1919).

What recourse then is there as between sovereign states where an act is done in one which is of detriment to another?

Presuming that an act is passed in one state without concurrent legislation in another, and that an attempt is made to take water from an interstate stream to the detriment of a lower proprietor in another state; as between a state and a citizen of another state, the way seems provided in the Constitution of the United States. The first step is a Bill in Equity in a United States Court having jurisdiction.

The diversion of this water would be a "tort" or wrongful act whereby legal damage is caused to a person, and the lower owner could proceed either in a Court of Equity for prevention, or in a Court of Law for Damages, to bring such proceedings in the Court of the State where the damage occurred or in the Courts of the United States.

How far a state can assume individuality of a damaged citizen in these proceedings, is a question for legal determination. Most of the law in this matter refers to individual property, i.e., riparian damages and not to a state in its sovereign capacity.

While the weight of modern authority or international law seems to approve absolute authority of sovereign states, this interpretation has been called a "harsh exercise of an extreme and hard law." With the weight of strict law in favor of sovereign rights, a spirit of conciliation and coöperation seems best for mutual advantage.

The states of the Union do not stand wholly toward each other as sovereign or independent states, and by signing the Constitution, the states by implication, agreed to do nothing that would be harmful to each other.

Possibly the Fourteenth Amendment to the Constitution has a bearing in this matter in stating "No State shall make or enforce any law that shall abridge the privileges or immunities of citizens of the United States" . . . . "nor shall any state deprive any person of life, liberty or property without due process of law."

Under this clause, riparian owners, but not necessarily the state, have recourse against an offending state, but the Eleventh Amendment prohibits suits in United States Courts against a state by citizens of another state.

Two systems of water law are recognized in the United States: Riparian Rights and Prior Appropriation.

The fundamental principle of riparian rights is that each riparian proprietor has an equal right to make reasonable use of the waters of a stream subject to equal rights of the other riparian proprietors likewise to make reasonable use. This, however, does not mean that all riparian proprietors have equal rights, but that each proprietor has a right to make reasonable use of the water for his own purposes to an extent that will not damage co-riparian proprietors.

The question then becomes one of fact as to what damage may be caused to a co-riparian owner, and the question of necessity and priority of use may well enter in.

Modern conception of water privilege designates, in order of importance: 1. Domestic Sanitation (water supply and sewage disposal), 2. Navigation, 3. Power and Irrigation, 4. Pleasure and Recreation.

It is, of course, inconceivable that an upper riparian proprietor would be denied life saving water, that a lower riparian might have a beautiful stream in which to enjoy aquatic sports.

The answer, unquestionably, is a reasonable allocation of the waters between all of the proprietors so that while either may not take the whole to the hurt of the other, each will derive some benefit of which he would otherwise be deprived. As regards most streams of water, there are periods of the year when there is such excess of flow as to be of detriment and danger to all riparian proprietors, and on the other hand, there are seasons of the year when the flow of the stream has so diminished from natural causes, that there also is danger and detriment from this condition.

If plans can be worked out whereby floods may be decreased and droughts avoided, surely a benefit to all proprietors has been accomplished. If also the present waste water from the flood period can be turned to the useful purpose of supplying needed water for domestic use and at the same time, by conservation, the flow in drought periods is measurably increased, surely a work of great public benefit has been accomplished.

The fundamental principle of the Law of Prior Appropriation is that the water user who first puts to beneficial use the water of a stream, acquires thereby the first right to that water.

The Supreme Court of the United States, by Article III of the Constitution, has sole jurisdiction in controversies between states and it may select from among various conceivable rules of solution,

that particular rule which, in the Court's opinion, seems best grounded upon reason. Among other applicable rules, there are at least four which seem outstanding:[5]

1. Each state should have for its people the quantity of water afforded by nature.

This rule is unworkable, because it is not possible for any state to have exclusive enjoyment of all of the water which falls upon it.

2. As a sovereign state, it has control of all waters arising within its boundaries whether supplying an interstate stream or not.

This rule is workable but harsh.

3. The waters of an interstate stream should be divided for the benefit of their respective peoples.

This is along riparian right lines.

4. The waters of an interstate stream should be divided between the states in accord with relative dates of use, regardless of state lines.

This is in accord with prior appropriation doctrine.

The reasonable solution of this problem of interstate stream control and use should be found in a method that will be for mutual helpfulness.

Three methods have been used in the United States to avoid or adjust controversies, potential or existing between states:

1. By direct legislation by Congress.

2. By suit of one state against another in the United States Supreme Court.

3. By compact between the states, approved by Congress.

The first is of narrow scope, because Congress can interfere only when permitted by its constitutional powers.

The second method is more inclusive, but is not entirely adequate, as it is difficult to secure execution of judgment against a state. The chief difficulty with this method is that not all matters of dispute between states are considered capable of judicial determination.

In view of this, agreements between states upon points in dispute, liable to cause friction, are desirable.

The Constitution forbids any "agreement or compact between States" without consent of Congress.

Several compacts between states have been ratified by Congress,

[5] Bannister: Interstate Rights in Interstate Streams, 36, Harvard Law Review, p. 950.

and this solution of interstate disputes, hitherto considered unapproachable, has afforded a remedy less troublesome than recourse to the Supreme Court.

One of the most recent compacts now in force, is that between New York and New Jersey for the purpose of developing port facilities. A noteworthy proposition for similar settlement, now in process, is the compact between New York, Pennsylvania and New Jersey, relative to the use of the waters of the Delaware River.

This is particularly applicable to the use by New York City of waters rising and flowing wholly in New York State, but proposed to be diverted to an entirely different watershed.

In discussing the diversion of water in England, the late Mr. George F. Deacon, M. Inst. C. E. and Chief Engineer of the Liverpool Water Supply, said:[6]

> Under modern legislation, no such abstraction of water is usually allowed, even if limited to times of flood, except on condition of an augmentation of the natural dry weather flow, and this condition at once involves the construction of a reservoir. The water supplied to the stream from such a reservoir, is known as "Compensation Water" and is generally a first charge upon the works.

A compact between states, ratified by Congress so that it becomes an irrevocable law, and embodying clauses providing definitely for certain allocation of water from interstate streams, seems to afford the best means of settling disputes of this character.

In view of the increasing demands for water not only as an incident to civilization, but as the most essential element in life itself, the time seems now at hand when all water sheds, and especially those in the more quickly settled parts of the country, should be allocated by national authority for specific purposes; some for water supply, others for waste disposal, both within reasonable limits and with proper gradation.

It seems probable that the immediate future will see greater coöperation among states themselves as well as among communities of the same states, which will tend to district development of water shed areas for the common good.

The time of "grab all in sight and keep what you can" regardless of present needs, is on the way to the discard.

[6] Encyclopaedia Britannica, Vol. 28. p. 398, "Water Supply."

The Supreme Court of Errors of the State of Connecticut said:[7]

> We must recognize that the problems of securing sufficient and suitable water supplies for our larger cities is an increasingly difficult one; that in reaching out beyond its immediate water shed, a city encounters the opposition of localities seeking to retain their former water courses for their own benefit.

In regard to Constitutional safeguards, it was well said by the United States Supreme Court that

> While the meaning of Constitutional guarantees never varies, the scope of their application must expand or contract to suit new and difficult conditions which are constantly coming within the field of their operation. In a changing world, it is impossible that it should be otherwise.[8]

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[7] Hartford Water Commissioners v. Manchester, 87 Conn. 209.

[8] The Nation's Health, Vol. 14, No. 1, January, 1927, pp. 59–60.

FLOOD DISCHARGE

By H. K. Barrows[1]

The section on provision for flood discharge, prepared by Mr. Weston E. Fuller, utilizes the same general formulae and methods suggested by Mr. Fuller in 1914.[2] In warning of flood possibilities the second paragraph, in view of the recent flood here in New England, is worthy of quoting in full, as follows:

> That an unobstructed flood channel, sufficient in size to carry safely the largest flood that will probably come during a long period of years, should be maintained throughout the length of the stream is essential in all parts of the country where the adjacent land is to be utilized for building of homes and for manufacturing purposes. The lands within the channel of great floods may properly be used for other purposes which do not restrict the ability of the channel to carry water and which do not involve loss of life or property, when the stream claims its channel for flood discharge. Failure to maintain such flood channels must inevitably lead to disaster.

Fuller divides flood factors into *two classes:*

1. Those dependent on or peculiar to a given stream, thus tending to make floods greater or less than for other streams. These are:

> Prevailing conditions of rainfall
> Size, slope and shape of drainage area
> Character of soil and vegetation
> Physical characteristics of channel
> Reservoir capacity
> etc.

2. Those general in effect on different areas but variable in time of occurrence. These are:

> Rate of rainfall
> Snow and temperature conditions
> Water stored in reservoirs, lakes and ground
> Velocity and direction of storm
> etc.

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[1] Consulting Engineer and Professor of Hydraulic Engineering, Massachusettes Institute of Technology, Boston, Mass.

[2] Trans. Am. Soc. C. E., December, 1914, p. 564 et seq.

The first class of these flood factors is taken account of in the Fuller formula by the expression $(C\ A^{0.8})\ (1 + \frac{2}{A^{0.3}})$, where "$C$" is a coefficient varying between about 25 and 200 and "A" is the drainage area in square miles. In this expression the first term represents the "average yearly flood" and corresponds to the mean of the maximum daily or twenty-four hour discharge for each year over a period of years. Where records are not available for a stream to obtain this term directly a suitable value of "C" from other streams may be used in determining this first term.

The second term gives the coefficient which if applied to an average daily flood will give the maximum short time flow or crest of the flood. As will be seen, this factor varies from about 2.0 for very small drainage areas to 1.0 for very large areas.

The second class of flood factors is represented in effect by the expression $(1 + 0.8 \log T)$ where T is the time in years. Thus, for $T = 1000$ years this term becomes 3.4, for $T = 10{,}000$ years it is 4.2, etc.

This term is one of probability or, better, may be considered as representing the factor of safety employed. Values are suggested for use varying from 1.5 to 2 for temporary works, up to 5 to 6 for structures where great damage would result or life would be endangered.

The complete formula for maximum or crest flood is thus:

$$Q \text{ max.} = C\ A^{0.8}\ (1 + 0.8 \log T)\ \left(1 + \frac{2}{A^{0.3}}\right)$$

A table showing flood discharge computed by many different formulae for different areas gives an interesting comparison and shows a wide variation in results.

A diagram is also given based upon $C = 100$ and a factor of safety of 5, which is convenient for use, as is also a diagram for obtaining "C" from the average yearly flood.

The effect of storage above spillway level in reducing flood peak is briefly explained, with a table showing this effect as percentage reduction from the maximum rate. The paragraph on spillways and their adequacy might well include a brief outline of the usual range in coefficients employed, or at least reference to where these may be found.

Fuller's flood formula has been well accepted and furnishes a good

working basis for analysis, although perhaps open to some exceptions. Thus the formula indicates no limit in possible flood or, in other words, given a sufficient length of time any flood amount may be reached,—an unwarranted assumption. The portion giving the crest flow coefficient has also not been well determined as yet, and shows decided discrepancies with actual flood data.

Since the Manual was prepared two additional flood formulae have been suggested which are of interest and should be given in the Manual. Jarvis[3] uses the form $Q = C\sqrt{A}$ and varies "C" to fit drainage area characteristics, with values between extreme limits of about 50 to 10,000. The diagram given by Jarvis, which shows very comprehensively all available flood data in 1925, might well be incorporated in the Manual.

Major Pettis[4] has recently developed the following flood flow formula:

$$Q = 328\ P\ W^{\frac{1}{4}}$$

where "P" is the maximum six-day rainfall in a period of 100 years, taken from the Miami Conservancy Technical Reports—Part V, and "W" is the average width of drainage basin (the area in square miles divided by the length of stream in miles). This applies for areas between 1000 and 10,000 square miles.

Taken as a whole the section on flood discharge furnishes a concise and usefull summary of this subject, in convenient form for general studies. At the best, however, the various formulae for flood discharge are only approximations and should be used as such. The Manual should state this and further suggest that specific cases should be carefully analyzed in detail, giving due weight to existing flood data, if proper conclusions are to be reached.

[3] Trans. Am. Soc. C. E., 1925.

[4] "A New Theory of River Flood Flow," 1927, unpublished.

WATERSHED PROTECTION

By E. Sherman Chase[1]

This chapter is divided into two parts, the first dealing with the general protection of watersheds and the second with industrial wastes, each part occupying approximately the same number of pages. Although the question of industrial wastes is not included in this present discussion, it might not be amiss to point out that the division of space is disproportionate, when the number of water supplies affected by general pollution on the one hand and by industrial wastes pollution on the other are taken into consideration.

The first part of the chapter might be expanded somewhat by the addition of more specific data relating to current practice in watershed sanitation. For example, the state departments of health of both Massachusetts and New York have enacted rules and regulations for the protection from contamination of many public water supplies within their borders. It would be of value to water works and health department officials to have available a brief abstract, say in tabular form, of the distances established in these and other states limiting the location of sources of pollution with respect to water courses, lakes and reservoirs serving as sources of water supply.

The chapter gives four classifications of watersheds, namely:

1. Relatively large inhabited watersheds where conditions are such as to require filtration.
2. Very small watersheds uninhabited and controlled by the water works authorities and where there is little or no storage in impounding reservoirs.
3. Watersheds with storage reservoirs large enough to hold the average runoff of many months or a year or more.
4. The intermediate type of watershed relatively small, exposed to pollution, where filtration is not adopted and where geological and other conditions are such that a moderately satisfactory water supply is procurable in the absence of filtration, provided that the protection of the watershed is given due care.

In considering watersheds as such, it does not seem logical to include in their classification the question of filtration. The char-

[1] Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

acter of a watershed is independent of the employment or not of artificial purification methods. A better grouping of watersheds than that given in the chapter would seem to be as follows:

1. Relatively large river watersheds with cities and towns thereon.
2. The watersheds of the Great Lakes.
3. Watersheds of moderate area with storage reservoirs or natural lakes, giving many months storage for the natural runoff.
4. Small or moderately large watersheds with little or no storage.

In the discussion of ownership of watersheds in this chapter no reference is made to the very real advantage from ownership of watershed lands due to the prevention of increase in population and attendant sanitary hazards. It is true that watershed ownership does not prevent all possible pollution, but it is of distinct value in forestalling conditions which may result in serious pollution. The ownership of marginal strips tends not only to protect the sanitary quality of water supplies, but also to make possible the protection of their physical qualities by the elimination of plowed fields and by the drainage of border swamps.

It would be distinctly helpful to water works officials if data were presented in this chapter with respect to the areas of watershed lands as actually owned.

In the discussion of the physical character of watersheds and water courses no reference is made to methods, such as swamp drainage, storm water filters, etc. which may be employed to improve the physical character of water supplies.

With respect to the detection of water borne disease, it might be well to refer to the fact that some water departments offer a reward for the prompt reporting of cases of such disease upon their watersheds.

In the matter of elimination of nuisances, no mention is made of the hazard resulting from ice cutting operations and the location of ice houses upon the banks of ponds or reservoirs. A fuller discussion of the various sanitary hazards upon watersheds would be valuable. The question of fishing, boating or other recreational use of reservoirs might well be taken up in more detail.

Some reference might also be made to the differentiation under some laws between temporary acts and sources of pollution which may be considered as misdemeanors and treated as such and those more or less permanent sources of pollution, such as barns, animal

enclosures, etc., the abolition of which can be brought about only by the payment of damages or through condemnation proceedings.

One general criticism which might be made of this chapter is to the effect that its tenor is to minimize somewhat the value of watershed sanitation, particularly where purification methods are employed. Granting that there are many watersheds upon which little improvement can be secured by any practicable method of watershed protection, it seems the better part of wisdom, whether purification is or is not employed, to maintain the sources of water supply in as cleanly a condition as possible. Purification methods are subject to the limitations of human frailities and if interruption of purification methods occur, the chance of unfortunate results as regards outbreaks of disease are much less with a reasonably well protected watershed than with one wholly unprotected. In the development of new or additional water supplies the present trend appears to be towards securing sources as free from pollution as possible and to utilize purification methods either to improve physical characteristics or to act as factors of safety as regards sanitary quality.

Strictly speaking, perhaps, the protection of ground water supplies does not belong in a chapter on watershed protection, but inasmuch as only half a page is given to safeguards against pollution of ground water supplies, it seems as though the whole subject of protection of sources of supply might be covered in a single chapter with the title "Sanitary Hazards and Protective Measures." In such a chapter or as an appendix, it would be helpful to include the tentative system of Sanitary Scoring of Water Supplies, approved by the New England Water Works Association at its meeting in September, 1927.

INDUSTRIAL WASTES

By H. W. Clark[1]

The "Manual of Water Works Practice," published two or three years ago, gives a chapter on this subject which I understand was largely prepared by Mr. Fales, a member of this Association and also of the firm of Metcalf and Eddy. In that chapter, covering about twelve pages of the "Manual," are paragraphs in regard to methods of solving industrial waste problems in connection with water supplies, kinds of industrial wastes involved in these troubles, number of supplies affected, and legislation in regard to such wastes. The kinds of waste reported at that time (1925) to have been detrimental to water supplies are summarized in a table and are 20 in number and show 245 supplies to have been affected. Of this total number, 107 were affected by coal mining washery wastes and acid mine drainage and 48 by coal distillation and coke manufacturing; that is, these two classes of wastes caused 60 per cent of the water supply troubles of this kind. Speaking from a local point of view we have practically no such problems in Massachusetts, although wastes from coal gas and water-gas manufacture have in one or two instances caused trouble, —one very serious, upon the Merrimack River many years ago, which was overcome by pretty thorough treatment of the wastes before entering the river, and one or two which diminution of pressure in water mains caused wastes from gas plants, or at least water tainted with these wastes, to back into the mains. These troubles were quickly overcome.

We have, of course, instances here and there of wastes from textile or other mills entering brooks or streams afterwards impounded for water supply purposes. Generally, a slight treatment of these wastes and long storage in reservoirs have overcome any trouble from them. Storage is a great factor in overcoming troubles of many kinds in connection with water supplies. The chief places in this country where wastes cause these troubles are where the water taken directly from a stream is immediately or almost immediately filtered

[1] Chief Chemist, State Department of Health, Boston, Mass.

and slow sand or rapid sand filters cannot be depended upon to remove the tastes and odors due to many of these industrial wastes.

The large volume of wastes, however, entering the Merrimack River above Lawrence from Lowell, Manchester, and other manufacturing cities on this river and its tributaries in New Hampshire and Massachusetts, has never affected the work of the Lawrence filters or the taste of the water coming from these filters. I imagine a considerable portion of this prevention of trouble has been due, in summer when the flow of the river is low, to the long storage in the millpond of the Essex Company reaching from Lawrence nearly to Lowell.

As I look over the list of wastes in the table given in the Manual I find many which, of course, never will trouble us here in Massachusetts and probably not in New England, such as beet sugar refinery wastes or corn products gluten settler wastes or wastes from oil wells or rice fields, etc. Our rivers, however, have wastes from pulp and paper mills, saw mills, tanneries, metal pickling, galvanizing etc., but fortunately these wastes in almost all instances enter streams not used for water supplies. I think it would be well, if this Manual is rewritten, to mention the states in which these troubles chiefly occur, the chief wastes in each state which cause troubles and typical methods of remedying these troubles if it is possible to do so.

So far as agencies for the control of pollution are concerned they are the Massachusetts Department of Public Health and the Department of Conservation. As the laws read, the powers of the Department of Conservation to prevent such pollution of streams as will endanger fish life, are stronger than the powers granted to the State Department of Health. Fortunately the Department of Conservation uses its power with judgment and in a reasonable way. It is a very serious thing in an industrial state, especially at the present moment when our manufacturing industries are being badly hit, to load them up with large expenditures for the purification of their wastes if we can for a time get by without such purification. As a matter of fact, one seldom finds a purification plant for industrial wastes that is adequate; that is to say, one that will prevent all nuisance. It may very largely minimize the nuisance; it may produce a large percentage of purification, but it is in the same class with sewage purification plants of municipalities. These plants of all kinds can be made so perfect that they will remove a very large percentage of the organic matter of the sewage or industrial waste

applied to them and hence reduce materially the pollution of the streams into which their effluents flow. They must always be operated under good management, however, to accomplish this and tastes and odors are often persistent. Throughout various parts of the country where this problem is pressing, much experimental work is being done and the results are being published in chemical, engineering and water works journals.

The chief criticism I could make of this chapter in the Manual is its brevity. If one had a problem of industrial waste pollution of water supply to solve, little information or help could be obtained from this chapter, good as it is. This is also one of the chief faults of certain other chapters in this Manual. An attempt has been made to cover too many subjects between its covers and this necessarily causes too great a condensation of certain chapters. The Manual should be enlarged.

TREATMENT OF WATER

By Robert Spurr Weston[1]

The speaker's part in the preparation of the book hardly fits him for a critic of certain portions. He has tried to be as detached as possible during a careful reading of the text.

CHAPTER VI, SELF-PURIFICATION OF STREAMS, LAKES AND RESERVOIRS

This chapter is admirably written and covers the ground in a very satisfactory way. In general, it is above the writer's plane of criticism. There is a typographical error in the table giving the subsiding value of silt. In this, the time required for particles 0.01 mm. in diameter to settle one foot should be 330, not 33.0 minutes.

In the bibliography, the reference to paper by the Sanitary Research Laboratory, M. I. T., 1917, should be to an "otherwise unpolluted," not "otherwise polluted" stream.

Regarding oily films on water and their tendency to prevent aeration, Professor Gorham of Brown University has found in the laboratory that these films do not interfere with the absorption of oxygen, but as every one knows, they do prevent wave action, and wave action furthers absorption.

CHAPTER VII, CHLORINATION

This chapter is written in the form of a delightful essay, and is very interesting to read. It contains much important matter. Whether or not all of it belongs under the title of Water Works Practice is a question.

It might be suggested that the historical portions of the chapter might be greatly abbreviated, and that the addition of a bibliography might serve to save the space devoted to some matters which do not pertain to practice, or which expound theories which are unnecessary for understanding the use of chlorination.

[1] Consulting Engineer, Weston and Sampson, Boston, Mass.

CHAPTER VIII, AERATION AND TREATMENT

The headings and arrangement of this chapter might be improved for clearness. The largest part of the field of water treatment is included in this chapter. Notwithstanding this, separate chapters are given to chlorination, deferrization, softening, ultra-violet ray treatment and ozonization, and treatment of water with iodide, respectively.

Under aeration, it is stated that only slight aeration is required for the removal of iron and manganese, but the scientific basis for this treatment, either in this chapter or in the chapter on deferrization, is lacking. It is not strictly true that "only slight aeration is required and excessive aeration is often distinctly detrimental." If there were nothing in the water but iron, manganese, mineral matter and carbon dioxide, the higher the degree of aeration, the better. What is true, however, is that certain waters contain so much organic matter that when the carbon dioxide is reduced by aeration to too low a concentration, the organic matter, which is a weak acid, combines with the iron, forming a compound difficult to remove by subsequent filtration. What is meant is not that excessive aeration is detrimental on account of iron removal, but because a certain amount of carbon dioxide must be left in the water to prevent certain interfering chemical reactions.

The tables under aeration might well be included in the section devoted to that subject. One leaves the subject of aeration and encounters table 9 under the heading of the next division of the chapter.

Natural subsidence, coagulation, rapid sand filtration

The arrangement of these chapters is under four sub-headings,—Descriptive features, Operation, Performance and Theory. The sub-headings are repeated under Natural Subsidence, Coagulation and Rapid Sand Filtration. While this arrangement is systematic, it leads to some repetition, especially under the headings entitled Performance and Operation, between which it is often difficult to distinguish. It also seems to the speaker that theory should preceed practice in the arrangement rather than follow it.

The section devoted to Natural Subsidence is only five pages in length, and is therefore rather sketchy. It would be well if statistical tables giving the results of basin and reservoir performance could be included in this section.

The section devoted to Coagulation, ten pages in length, seems over-condensed. More statistics regarding sizes of basins at various plants, the relation between quality of water and basin sizes and more descriptive matter regarding various devices for applying coagulants, should be used. It seems as if the authors had been too conservative in avoiding the mention of commercial apparatus and descriptions thereof. A list of devices with names and addresses of makers would not be out of place.

In the mention of the usual velocities in reaction chambers or mixing tanks of 1 to 2.5 feet per second, the authors probably have neglected to consider soft colored waters, which form a delicate floc with coagulants, and which form better flocs when handled at velocities of less than 0.5 foot per second.

Mention should be made of the use of copper sulphate in coagulation basins to prevent growths of algae, as practiced at Norfolk, Virginia.

The speaker sees no reason for such a great variety in methods of chemical expression. It seems incongruous to use the term aluminum sulphate and sulphate of alumina on the same page with ferrous sulphate and hydroxide of iron. A uniform plan of giving the scientific name first, followed by the trade name, and of using one name throughout, is to be recommended.

The writer probably does not mean that "ferrous sulphate in crystal form is now little used" He probably means that material in large crystals is now little used—the so-called sugar sulphate being a form of ferrous sulphate which is in fine crystals.

The use of the hydrogen ion concentration determination should be explained more fully, and examples of optimal pH values for various waters should be given in tabular form.

The description of rapid filter practice is good. This remark applies equally well to the sub-titles of operation and performance. There is, however, some repetition under these two latter, e.g., regarding the rate of filtration.

On the whole, a general criticism may be offered that the section departs too much from the case method. In describing water works practice, which is the title of the book, a few more concrete examples might be given regarding rapid filters such as are given on page 230 regarding slow filters.

The section devoted to rapid filters suffers greatly because of poor indexing.

The speaker would suggest simpler language for the sake of wider reading. For example, such expressions as "correlation of two variables" are rather too mathematical for ordinary understanding.

Slow sand filtration

There is little to criticize under this heading. This section is clearly written and records a practice which is so well established that only minor criticism can be made. However, mention of Clark's method of loading slow filters with aluminum or iron hydrates for color removal should not be omitted from future editions. This method has not received the attention which it deserves.

The general criticism of this chapter is its lack of uniformity and the speaker suggests that it be expanded and rewritten perhaps by a committee of the former writers who could agree on uniformity of style and methods of expression.

CHAPTER IX, DEFERRIZATION AND DEMANGANIZATION

The treatment of the subject matter in this chapter is good. Perhaps this lacks on the theoretical side, as the former chapter does on the practical side.

Regarding subsidence following aeration, consideration of the time element should be given. At Brookline, Massachusetts, the period of detention and contact in a baffled subsiding basin has proved decidedly beneficial. The rusting of iron is analogous to coagulation, and the speaker believes that if slow movement is produced as at Brookline, the degree of iron removal is increased.

CHAPTER X, SOFTENING

This chapter, which embodies the latest results in practice, is well written, is of about the right length, and needs only a few examples from practice, with results of analyses, to bring it above criticism.

Only one and one-third pages are devoted to the important subject of zeolite treatment. This seems too little. The kinds of zeolite are not given, nor are there any examples from practice. Here again manufacturers names might be mentioned.

CHAPTER XI, ULTRA VIOLET RAY TREATMENT AND OZONIZATION

This brief chapter seems to cover the ground in a satisfactory manner, although the high costs of the processes might be exemplified by figures.

CHAPTER XII, TREATMENT OF WATER WITH IODIDE FOR THE PREVENTION OF SIMPLE GOITER

Sixteen and one-half pages are devoted to this subject, and only sixteen pages to rapid sand filtration. The historical portion of this chapter might be greatly decreased and replaced by a bibliography, and in view of the fact that the use of iodized table salt is more practicable than the use of iodized water, a large part of the space in this chapter might be used for expanding the sections on rapid filtration and coagulation.

As for general criticism, the first is that there is too much variation in style. The theory of coagulation, for example, is, and perhaps necessarily, not sufficiently exemplified to make it clear to the untrained reader. On the other hand, the chapter on deferrization is perhaps too empirical and practical. The chapter on softening seems to the speaker to be a happy medium, and as said before, it would pay to have the literary and scientific styles of these various chapters and sections equalized.

As others have noted, the main deficiency of the book lies in its index. This makes it almost useless as a book for ready reference. This fact is a defect which may be easily corrected in future editions.

In general, the work reflects great credit upon those who wrote and compiled it, and especially on Mr. George W. Fuller and his associates on the Council of Standardization of the A. W. W. A., whose unremitting energy and inspiration have produced this highly creditable and remarkable work.

DISTRIBUTION SYSTEMS

By George H. Finneran[1]

In reviewing with a more or less critical inclination, the Manual of Water Works Practice, compiled by the American Water Works Association, one should consider first of all, that information in the form of a manual is necessarily abridged; and secondly, there is so much in the construction and maintenance of a water works, dependent upon local conditions, and those conditions vary so much from place to place, that to attempt to guide or prescribe practice by certain set rules, directions, and formulae, will result unsuccessfully.

There are, however, to be found in the Manual, underlying principles, which, if applied with the modifications called for by particular conditions, will cause to be realized, in a more or less general way, the desired ends. In the application of these principles, as well as the more detailed instructions and specifications, one is likely to have a little difficulty because of a certain vagueness as to methods and technique.

I think the average water works man, who is confronted with a new situation, or is anxious to get better results along a certain line, and who resorts to the Manual, expecting to receive helpful information, will *sometimes* close the book with a feeling that he would still like to have a little more specific information, and direction as to methods and means. I do not think, however, that this applies generally throughout the book. On the contrary, I find much valuable detailed and explicit information in many of the chapters.

Might it not be well in some cases where the reasons and methods of arriving at certain conclusions are somewhat obscure, to use textbook methods and give concrete examples showing the successive stages and steps in the solution of the problem at hand. It might be regarded as a little too elementary by our "high-brow" friends, but it would be justified by the results attained—viz.: a more intelligent understanding of the subject matter by those who find it necessary to have recourse to the Manual.

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For instance, in planning that part of a distribution system, consisting of the primary feeders, secondary feeders and the distributors, or grid-iron arrangement, for the purpose of original installation, or reorganizing in sections where consumption conditions have changed, or extending in newly developed parts, it would be helpful if one were advised a little more fully and in more detail as to the several types of a primary system particularly type III, the "dual-flow." Why not describe some typical and highly rated plant of that type?

As to the feeders themselves, described in the Manual as "constituting the skeleton of large pipes with relatively wide spacing which convey large quantities of water to various points in the system for local distribution through the smaller mains"—their size is determined by the demand they are expected to supply, but there is not much information as to their proper location with reference to the secondary and distributor mains. While there may be certain factors regulating this, such as topography, high and low consumption areas, high and low fire risks, sizes and locations of secondary and grid-iron pipes, etc., yet I think it desirable to impress upon designers and builders the necessity of spacing primary feeders as far apart as possible with due consideration for the factors mentioned.

It will be found in the older cities that several large mains are laid in the same street, or they are confined to a certain narrow section, or they converge to a certain focus—usually some point in the heart of the city. The disadvantages of such a layout are apparent.

As a rule, primary feeders extend from the reservoir or pumping station on one side of the city in the direction of its opposite boundary line. The flow seems to be generally away from its source. In the case of a city that "fans out" considerably, the feeders may radiate somewhat from the source, but, in both cases, there is the possibility of an absence of proper tieing together of the ends. It is somewhat suggestive of a wheel with its hub and spokes, and either the whole or parts of the rim missing. I think the Manual should recommend the desirability of laying separate feeders from the reservoir or pumping station, to carry a flow without take-off, to the extreme limits of the city and thence towards its center, to connect with and reinforce those lines traversing the settled parts, the flow in which has become attenuated. This arrangement might more simply be termed a "back-feed." A condition that calls for such treatment will usually be found where development has been fast and small sized mains with

here and there a secondary feeder, have been laid and extended in all directions without receiving proper support from primary feeders.

In connection with this matter the growing practice of city planning and zoning should be given some attention. If a water-works management could have some fore-knowledge of the street layout in undeveloped sections, and the character of the development, whether business, manufacturing, or residential, it would greatly aid in providing a proper supply for that district without the necessity later of making alterations in the "root end" of the system, or impoverishing the supply in adjacent territory.

Pitometer flow-tests sometimes reveal noticeable inequalities in the flow of different feeders and other pipes of the distribution system. Some mains are carrying more or less of a burden, while in others there appears to be scarcely any flow. Such a situation should be treated in the Manual.

Another matter that might be recommended or urged, is the desirability of laying two mains in streets of more than 50 feet in width. In a street 40 feet wide, it is customary to lay the main about 13 feet off from one side and 27 feet off from the other. In a street 50 wide, the main is usually laid 17 feet off on one side and 33 feet off on the other. House connections on one side of a street of 50 feet width will necessarily be 33 feet long. A service pipe of that length or longer, with its tap, a curb cock, and a meter, will have a comparatively large loss of head, and its first cost, plus maintenance, such as leaks, freezing, electrolysis, pavement replacement, etc. may run into quite a figure. With regard to electrolysis, a service of that length will lie under the street railway tracks and will be more favorably situated to collect or discharge stray current than if laid either in or near the sidewalk.

Where two mains are laid in a street one need be only 6 or possibly 4 inches in diameter, while the other should be large enough to support hydrants and supply the fire draft. If practicable, both mains should be laid in the sidewalks thus saving openings in the roadway pavement. The corporation cock can be used as a curb cock, and leaks are more quickly noticed.

FIRE DEMAND

Providing an adequate supply for a maximum fire demand plus maximum ordinary draft is a matter which, as stated in the Manual, must be decided on the ground. There are so many varying condi-

tions that may enter into the situation that each locality should be treated by itself. As also suggested in the Manual, hydrant flow-tests should be made frequently and results noted. It should be strongly urged in the Manual that these tests be made regularly and systematically so as to cover all parts of the city. They are an excellent means of exposing weak spots in the system. No portion of the occupied areas of the system should be omitted as it might be that particular locality that would furnish a demand that could not for some reason or other be satisfied. It is unnecessary to urge that any deficiencies uncovered should be corrected at once.

The recent conflagration in Fall River, Mass., called for a maximum fire flow for a period of eight hours, and unofficial information furnishes figures that would indicate a flow of over 26,000 gallons per minute during the first 5½ hours of the fire. This is somewhat greater than the amount allowed by the Underwriters for a city of the population of Fall River (see page 300, Manual of Water Works Practice). It is hardly fair, however, to apply the Underwriter's table to the recent fire at Fall River, as that was an extraordinary one, but not greater than may occur in any number of cities throughout the country. It is well that cities where fires of magnitude may occur should be prepared for the same.

Reverting to the dual-flow type of supply to a distribution system, it seems to me to be the most desirable type in so far as its combination of gravity and pumping is concerned. It economizes in pumping during periods of low demand, usually after business hours, and it is there with the required pressure during ordinary peak and extraordinary peak, including maximum fire demand.

There is one thing to bear in mind in connection with combining accelerated pumping with a gravity supply during periods of extraordinary demand in parts of the city where the pressure is ordinarily low by reason of its elevation, its remoteness, or absence of connection with a primary feeder, and that is the fact that, in order to meet a demand for more pressure in one particular section of the system, the pressure has to be correspondingly raised throughout the entire system. That means a dissipation of force. If it were possible to do with a water supply what is done in warfare, viz., mass the reserve troops at that point of the front where the fighting is taking place, then the problem would be much simplified. A serious possibility during the boosting of pressure throughout a general area is the failure of weak spots in the piping system. Any failure in a large

main at this time would defeat the object for which the raise in pressure was made.

The tendency towards higher pressure and greater volume in present day communities seems to be pronounced. I presume it is due to an increased domestic demand, although the per capita figures do not reflect it. I think it is due to the offsetting economies realized by metering, and prevention of unmetered waste and leakage.

However, if one analyzes present day domestic conditions he will see a much more generous use of water than formerly. Large buildings, hotel and office, present day plumbing, street flushing, the extensive use of concrete, automobiles, golf clubs, gymnasiums, indoor swimming, athletics which induce bathing, and here I may say, strange as it sounds, people generally bathe oftener than in the old days. And still stranger, I think that people drink more water than formerly, due not as you may think to prohibition, but to the widely circulated advice of our medical friends. Manufacturing is carried on in cities and large towns now more than formerly because of the labor supply and more water is accordingly used in process work.

My purpose in reciting these seemingly irrelevant explantions for the increased use of water for domestic purposes is to suggest to those engaged in the revision of the Manual, if there is to be any, the consideration of those factors that influence the domestic demand, and thereby assist those who are constructing or altering a distribution system to forecast more accurately the probable consumption.

In the matter of fire draft, the underwriters have made the calculation of an ample supply more or less simple through certain empirical formulae or data furnished in their reports, but with regard to domestic demand, there does not appear to be any information as to the probable requirements in one street or another, or in one section or another. If a city or town is 100 per cent metered, the domestic consumption in a particular street may be computed from the meter readings, and the required total supply for that street arrived at by adding to the domestic consumption the unmetered waste and leakage and the estimated hydrant supply. A pitometer measurement is necessary in order to learn the unmetered waste and leakage. The consumption records from meter readings, if sufficient in variety and number, and properly classified, may be used as a basis in estimating probable demand in new sections. They also assist in

determining the proper location and layout of the primary and secondary feeders.

It is a rather complicated matter, but it seems as if it might be treated with more detail and in a more simple and helpful manner than we find in the Manual.

MATERIALS

It appears to be taken for granted in the Manual that cast iron is the best material for use in pipes of a distribution system, with exception made in the case of pipes above 30 inch diameter, where it slightly favors steel. It does mention reinforced concrete and wood-staves for large transmission lines between sources and storage, but as I am considering the strictly distribution end of the system, I shall exclude those two materials.

Until some material is produced that will combine the strength of steel with the durability of cast iron, I suppose that cast iron will have the call. With the continued advance in industrial chemistry there is good reason to hope for such a material in the near future. For the present there are places where cast iron pipe may be used to advantage and likewise there are places where steel pipes will give better service.

I think many of us would like to have the Manual give us more information as to the relative merits of plain cast iron pipe, variously coated steel pipes, variously jointed steel pipe, cement lined steel pipe, cement lined steel pipe with outside covering of cement mortar or concrete, horizontally cast pipes, vertically cast pipes, bells up, or bells down, spigot ends with or without shrink-heads, centrifugally cast pipe, sand-spun, green sand mould, dry sand mould, etc. etc.

The manufacturers of this variety of pipe all claim that his is the best. Why not an expression on that point from the users?

Recently it has been whispered that a cement lined main carrying water of certain quality at a slow-rate of flow has to be frequently flushed to prevent said water from discoloring aluminum containers or cooking utensils. Is that so? Is there anything to it? Is the cement lining the cause, or what not? The Manual might tell us something about that.

So long as I have started in a questioning manner, I shall continue, as I think it a good way to get information on certain points that I am unable to find in the Manual.

IMPORTANT QUESTIONS

Does lime wash or lime in the backfill protect a cast iron pipe from exterior corrosion in salt marsh soils?

Is there any certain protection from vibration for pipes laid under railroad tracks in unstable soil?

Are there any data on the allowable weight of backfill on pipes of steel or cast iron of large diameter? How much of a factor is the resistance of the pipe bed?

Are there any approved proportions of impurities in cast iron used for water pipes, or in other words, what percentage of silicon, of phosphorus, of sulphur, of manganese, of free and combined carbon is allowable? How should it be physically distributed? Is there likely to be more free carbon in a thick wall than in a thin wall? Is a thick cast iron pipe relatively stronger than a thin one? Is there any internal galvanic corrosion in cast iron? Does it vary with the percentage of its impurities? Does it vary with the manner in which its impurities are segregated? Is there a safe allowable percentage of scrap iron in cast iron pipe? Is it advisable, or is it necessary to have foundry inspection by the purchaser? Is it advisable or necessary to have an inspection during unloading at point of delivery?

What are we to do about cracks concealed by tar coatings when they come to our attention after being laid?

What are we to do about blow-holes exposed in machining?

What are the relative merits or demerits of foreign made pipes as compared with domestic?

Is there anything new and superior in cast iron or steel pipe coatings?

What is the relative merit of Hydro-Carbon coating?

What is to be said about Victaulic joints?

What is to be said about Universal joints?

What about lugs and straps versus single or double grooves in high pressure lines, or in positions of unbalanced pressure?

What is thought of tin mixed with lead to increase the stiffness of joint?

What about joint compounds versus lead for joints?

Are Dresser joint clamps effectual in preventing leaks where there is vibration and some settlement?

In pouring lead into a large diameter joint, is there anything to be said about the expulsion of the air as it is displaced by the molten

lead? Can any provision be made for its escape, and are these provisions usually taken?

If there is a movement in a bell and spigot joint due to settlement, does the jute back of the lead prevent the beaded end of the spigot from moving forward? Would a hard gasket be more effective than jute? Is a solid joint the answer?

What is to be said about the precaulked joint?

Is the importance of a uniform depth of joint sufficiently stressed?

Is the danger of concentrated calking sufficiently recognized and warned?

Has the effect of variation in the temperature of water in cast iron pipes ever been noticed? Has it been noted in cold climates when the coming of the winter has been sudden and the drop in the water temperature likewise, that breaks, usually in large mains, have occurred more frequently than at other times? Does the same thing occur when conditions are reversed and the water becomes warm?—or is it just imagination?

And so on—these are a few of the questions that could be answered by the authors of the Manual with resulting helpfulness to the poor water works man.

Before leaving the subject of mains, I should like to suggest that under the heading of gate valves, the Manual might give some instructive information on the following points:

Enclosed bevel gears, lubrication, roller bearings, frictional resistance in guides of solid wedge valves, material for packing stuffing boxes, types of chambers, ventilation of same, by-passes, hand holes for removing seat accumulations, power devices for lowering and raising large gates, roadway boxes for valves of smaller size, etc.

I should also like to suggest that the Manual mention the desirability of water works officials making an effort to have some regular locations allocated to the various underground corporations. In keeping with conditions on the surface, the space underground is becoming congested. Gas, water, electricity, telephone, sewer, cold storage, pneumatic tubes, telegraph, street railway, fire alarm, etc. are all huddled together, over, under, and alongside. Each should have its own regular location assigned with reference to the other's special needs. If something is not done in this matter, there will be chaos. Some principles governing the matter should be set forth and some constructive ideas graphically displayed to aid in the satisfactory solution of the matter.

SERVICES

The chapter on services seems to cover the ground pretty well. The service pipe question is a local one. Corrosive qualitities of the water and soil should be the determining factors in the choice of a material.

While some localities may supply their consumers through plain wrought iron or steel pipes, economically and efficiently, others find it necessary to use those of lead, brass or copper.

If small sizes of cast iron pipe can be lined as successfully as the larger sizes used for mains, it would seem that they should meet about all difficulties and requirements with the possible exception of breakage due to shock or settlement.

Copper tubing seems to be very attractive at the present time. It is hard to build up an argument against it. It would be well, however, for those contemplating its use to read the papers read at a New England Water Works Association meeting about a year ago by Dr. Mallory of the Boston City Hospital and Director and Chief Chemist Clark, of the Massachusetts State Board of Health. It might assure them on the question of copper poisoning, or inform them as to conditions approaching the danger line.

The matter of charging for house connections might be considered. While that point also is more or less a local one, yet there are certain principles underlying the matter. Should water be considered as a commodity sold to the consumer like gas, electricity, fuel, clothing, or food?

As such commodities are usually delivered to the consumer on his property should not water also? On the other hand, there is no competition in the sale of water. The business is a monopoly, and as such, the purveyor may make his own terms. An equitable way out of the matter would seem to require the owner to pay for the installation and the water company or municipality to do the work as far as the property line and maintain the service to that line afterward. Where the foundation wall abuts the property line, I think it advisable for the water company or municipality to stop short of the wall and require the owner to come through to the outside and connect. A great many leaks occur at or in the foundation wall and complications arising out of the same may thus be avoided.

Some instructive information should be given in the Manual for the clearing of clogged pipes. The thawing of frozen pipes appears

to be handled quite fully and instructively in the chapter devoted to that subject.

A matter that seems to require more light is that of grounding electric, telephone and radio wires on water pipes. Is it a safe practice? Are there any injurious results, or possibilities of the same? It is sometimes difficult for the mind to clear itself of apprehension over the question as to what becomes of the current that is taken on by the pipe. It does not remain. It must leave the pipe somewhere, and at the point of departure, does it leave some injurious evidence of its presence? Or, is it all too small a matter to worry about?

Could not the Manual contain some educational matter that would assist the official in determining the proper size of service pipe to install. As most of us know, the tendency of builders and owners is to ask for larger pipes than they actually require. This is contrary to our conception of good policy. The Manual expresses the objectionable features concisely and to the point; but the question still remains as to how to arrive at a size that will be adequate, but not excessive. There are plenty of data extant on this subject, but I do not find them in the Manual.

PRIVATE FIRE PROTECTION

Furnishing connections for private fire protection is a fast growing practice. The increasing use of automatic sprinklers is the cause. Some standard policy should be evolved to cover the physical and financial phases of the matter. If practicable, both financially and physically, the water utility should provide separate mains carrying a sufficient pressure to satisfy the requirements of the National Board of Underwriters, for connections of this kind.

Where it is necessary, in order to supply the domestic demand in high buildings, to have two grades of service, commonly called high and low, and both in the same street, it is an easy matter to segregate the sprinkler supplies in the high service, but where only one grade of service is maintained, it is rather a large request to ask for a special main for those supplies. However, from a fire protection standpoint it works out nicely that way. With sprinkler mains breaking in buildings on fire, or with all heads open, no pressure drop will occur in the hydrant supply, which presumably is from the low service. On the other hand, if the low service is out of commission through accident, the sprinkler service is ready for effective operation.

It is well where the two grades of service are in the same street to have a hydrant here and there connected with the high service to provide a fire pump supply in the event of a shut down in the low service main.

Four-inch is the largest diameter advisable in a sprinkler supply pipe. If more volume is required, it is better to have two such connections. With two connections there is less likelihood of the building being without sprinkler service as it is very rarely the case that both connections are out of service at the same time.

A 4-inch sprinkler supply presumes a street main of no less than 6-inch diameter. Where two connections are laid they should be, at least, 30 feet apart if the frontage will allow. If more than two connections are necessary it is desirable to have them come from separate streets, if that is practicable.

Where the sprinkler layout is not extensive it is very often practicable and quite desirable to furnish service through one general supply pipe of sufficient diameter, and metered with a fire flow meter. Otherwise, the expense would be prohibitory to place meters on every fire pipe. Sealed valves and frequent inspections will have to be depended upon as a protection against use of water for other than fire purposes.

Most sprinkler systems are now equipped with an alarm that operates when water starts to flow in the pipes. All fire supplies should have a check valve to prevent back-flows.

Notwithstanding the statement in paragraph six, page 617 of the Manual, that the water utility, whether public or private, should pay for the service connection from the main to the property line, I think that, if it is reasonable to charge a consumer for his domestic connection through which a revenue is derived, it certainly is reasonable to charge an owner for a fire sprinkler supply pipe, through which no revenue is derived and which enables said owner to receive a generous reduction in his insurance rates. I certainly advise charging the full cost of installation, and, furthermore, imposing a yearly "stand-by" charge for the maintenance of a working supply in the system. I should also make it part of the contract that the city or water company should not be held liable for personal injury or property damage resulting from any accident or defect in the supply pipe or its appurtenances.

This whole matter of private fire protection is what the name implies, a "private" matter. It is a one way affair. The gains are

almost all on one side, and to balance the same the water utility, whether public or private, should receive some recompense or be absolved from liability, or both. If the said private fire protection, and I have in mind principally, automatic sprinklers, should relieve the municipality of the necessity and expense of maintaining a fire department, it would be an entirely different matter.

As the writer in the Manual states, the remedy for fire hazard should not be looked for through free fire protection service, but through a proper reconstruction of the building codes and fire laws and their strict enforcement.

CONCLUSION

There are so many other subjects kindred to distribution to be found in the Manual, that I have not the time or space to comment on them. Each and everyone is important, and each and everyone has much of value. All the subjects are presented in an admirable manner. They are of great educational value. They have given me a new insight into many otherwise obscure matters. They lead one to other points of view. They are a credit to the authors and compilers, and I feel rather apologetic with my small criticisms and possibly valueless suggestions. However, my remarks are not intended as criticisms. They are merely the expression of thoughts and ideas stimulated by the Manual.

It is a fine book and no water works official should be without it.

PUMPING STATION PRACTICE

By F. W. Dean[1]

BOILERS

There has been for a century a competitive spirit among the managers of pumping stations concerning the so-called "duty" of pumping engines. The earliest case was probably in England and especially in Cornwall where pumping engines were used for draining mines. This is a district near the Welsh coal fields, and where coal was always cheap, but nevertheless the effort to save coal was constantly made. The Cornish engine was developed there and it was a great advance over earlier types. It violated various principles of heat economy, as now well understood, but it persisted beyond the middle of the last century, the last prominent case of its installation in this country being at the Pettaconsett Pumping Station of the Providence, R. I. water works.

The part that the boiler played in this competition was not so well understood in the early days as now. This was due to the fact that combustion is a chemical process and means of determining the perfection of the process had not developed. It is now known to many that there is a great difference between the efficiencies of boilers when differently fired. The term "efficiency" is now used instead of "evaporation per pound of fuel from and at 212°F.," as it is more scientific.

The efficiency of a boiler is the proportion of the heat which would be derived from complete combustion of the fuel under ideal conditions, that enters the water and steam in an actual case. The majority of boilers are probably giving an efficiency of from 50 to 70 per cent, while within a few years this has been increased to more than 90 per cent. These very high efficiencies come not only from excellent combustion, but from the utilization of as much of the heat as practicable that escapes from the boiler towards the chimney. This heat is not only utilized for heating feed water, but also for heating the air for combustion. Some advantage comes also from reduc-

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ing the heat lost by radiation, although this is a comparatively small amount.

Economy of fuel is given great consideration in pumping plants at the present time, but in most of them it would not pay to go to extremes in the installation of means of economy. It is a duty, however, which everyone should feel, to economize fuel, and financial economy should not always be the end sought. The draft upon the fuel resources of the world is enormous and they should be conserved as much as practicable.

Most pumping engines are driven by steam and the boiler, therefore, is a necessary part of the plant. There are many incorrect ideas concerning them, but in a general way it can be stated that a boiler is a device for extracting heat from hot gases. There are, therefore, two principal things to be done, one, to burn the fuel so as to produce the maximum quantity of heat from each unit of weight, and the other to use a boiler that will most completely absorb the heat.

It is evident that there may be many forms which the boiler may take, but it should be remembered that the circulation of the hot gases thoroughly throughout the heating surfaces, and the possibility of keeping the surfaces clean are the most important.

There are two general classes of boilers, which are known as fire tube and water tube. The former has the water contained in a metal shell through which tubes pass, and through these the hot gases proceed to the chimney. In the water tube type there are also many small tubes connected at each end to so-called headers or to drums. These parts contain water and the hot gases pass around the tubes and to some extent in contact with the headers and drums, and give up their heat to them.

While it is not difficult to make the hot gases pass through the tubes of fire tube boilers, since there is no other place for their passage, it is difficult to make them circulate around the tubes of a water tube boiler. In fact it cannot be thoroughly done and much of the surface of a water tube boiler is never reached by the hot gases. The gas circulation is directed by fire resistant tiles placed, after much experimentation, in the most advantageous positions. As gases, however, take the paths of least resistance, and as near straight lines as possible, they omit in their travel, as before stated, contact with a considerable part of the surface.

Fire tube boilers are made in various ways, the most usual form in this country being the horizontal return tubular boiler which con-

sists of a horizontal shell with tubes running from one head to the other. It is set in brickwork and the fire is underneath. It possesses several good features. It is low in cost and is a boiler of maximum efficiency. All of the tubes pass about the same amount of gas because the distance from the end of the grate to the uptake is the same through any tube and for this reason the resistance to the passage of gas through all tubes is the same. It is commonly asserted that the upper tubes pass more gas than others, but if an accurate determination were made it would probably be found that the difference is small.

The heating surfaces of the tubes can be thoroughly cleaned by blowing and scraping and the efficiency can be maintained. The water surfaces of the tubes cannot be so well kept clean but various means can be used to contribute to this. In water tube boilers the reverse is true. The interior of the tubes, which are in contact with water, can be quite successfully bored out by machines for the purpose, but the fire sides of the tubes cannot be cleaned with any degree of thoroughness. It is done by steam jets, and those parts of the tubes that are directly struck by the jets are well cleaned and the remainder is not The dirt increases in straight tube boilers from one side of the boiler to the other, but in bent tube boilers modern tube blowers are run across and are much more effective than hand blowers. It should be said, however, that modern blowers do some good with straight tubes.

Horizontal return tubular boilers

There is much erroneous information promulgated with reference to horizontal return tubular boilers. It is commonly asserted that they contain more water in proportion to the heating surface than water tube boilers. The opposite, however, is the truth, as anybody can ascertain by computing the water contents of examples of each type. There is no harm, however, in having a large water content, as after the water is once heated to the temperature of the steam any further addition of heat does nothing but make steam, and does not have to raise the temperature of the water. The heat required to raise the extra water to the maximum temperature is comparatively small.

It is also commonly asserted that the horizontal return tubular boiler cannot be forced, and that the water circulation is poor. In order to force it it is merely necessary to burn more fuel as in other

boilers, and the output of steam increases pro-rata. In regard to the circulation this takes care of itself and it cannot be stopped. It may be slow because there are so many spaces in which it can occur. Water tube boilers circulate the water rapidly through the tubes nearest the hottest gases because the areas are small, and being in tubes its velocity can be measured by suitable apparatus. This probably cannot be done in horizontal return tubular boilers. Horizontal return tubular boilers are in many cases forced daily, twenty four hours, per day, from 200 to 300 per cent of rating, and more.

Another superior feature of horizontal return tubular boilers is the small draft loss, which is about two thirds that of some types of water tube boilers. For this reason less chimney capacity is required than for others and there is less difficulty in forcing them.

If high ratings are required it is advisable to weld the tubes into the back head after they are expanded and beaded in order to prevent leakage. In such cases it is not uncommon to weld the circular seams on the lower half after they are caulked. The back head seam for some reason does not need welding.

The limitations of horizontal return tubular boilers are in size and pressure. The largest practicable size is over 100 inches and it is said that they have been built as large as 120 inches, and 96- and 108-inch boilers have been made. Many 90-inch boilers having 260 three inch tubes 20 feet long with 4027 square feet of heating surface are in use, some of them being operated at 300 per cent of rating. Boilers 102 inches in diameter can be made for 200 pounds and with 5000 square feet of heating surface giving a rating of 500 horsepower.

The old way of making horizontal return tubular boilers with three courses is being abandoned and replaced by two courses in order to reduce the number of joints exposed to the fire. Plates can now be obtained over 15 feet wide, and there are bending rolls much wider than this.

Plates 2 inches thick have been used in marine boilers, but 1 inch may be stated at present as the limit for horizontal return tubular boilers. A study of the theory of the transmission of heat through metal plates shows that increases of thickness make practically no difference in the transmission.

The ordinary design of the means of supporting horizontal return tubular boilers is defective, and should give way to the three-point method, as this is the only way to insure that all supporting parts will have the intended stress during the life of the boiler.

There is no objection, in order to make the most of horizontal return tubular boilers, to placing the tubes $\frac{3}{4}$ inch apart, and many are so made. Nothing is gained by using a wide center space between the tubes.

The steam nozzle should always be placed in the middle of the boiler in order to draw the steam toward the center from all parts and thus diminish the tendency to drag the water along with the steam and cause priming. A perforated pipe should be placed within $\frac{1}{2}$ inch of the top of the boiler the area of each branch of which should equal half the area of the nozzle. The perforated pipe should be as long as the boiler, or as near that as practicable, and the holes should be $\frac{1}{2}$ inch in diameter along the length of the pipe. The total area of all of the holes should be not over that of the nozzle. The manhole should be strongly reinforced as this is a weak part of a boiler. Rivet holes should always be drilled in the solid plate without preliminary punching, with the plates in place, as thereby the holes necessarily match and the plates are not injured by punching.

The longitudinal joints of boilers are now always butted, and this has converted horizontal return tubular boilers from dangerous to safe boilers, until now there is no safer boiler. The rivets should be driven by a hydraulic machine which derives its power from an accumulator.

Most boilers are provided with too large steam pipes. These pipes are loafing places for the steam, and the smaller ones are cheaper, are more easily bent, permit expansion and contraction with less strain of joints, require smaller valves, less covering, and radiate less heat. It is found by trial that there is practically no loss in pressure by the smaller sizes. The sizes of nozzles and steam pipes should be as follows:

	inches
For 60-inch boilers	3
For 72-inch boilers	4
For 84-inch boilers	5
For 90-inch boilers	6
For larger boilers	7

Setting of horizontal return tubular boilers

It has been the custom to build settings with air spaces, having firebrick inner wall and a red brick outer wall. These spaces are likely to cause leakage of air into the furnace, cool the gas, do not promote combustion to any important extent, and are not controllable.

They reduce the stability of the setting and introduce weak connections between the red and fire brick walls. These settings should be built with solid firebrick of the same size using high grade brick next to the fire and low grade elsewhere, in order that the high grade can be accurately bonded with the low grade. The low grade brick costs some $18 less per thousand than the high, and about the same more than red brick. The difference in price of the firebrick over the red will be saved in the diminished labor of cutting and fitting, with a far better piece of work. The side and center walls should not be built solid with the front and back walls, but should have expansion spaces where they meet those walls. These spaces should be secured by building in $\frac{7}{8}$ inch boards so as to make it certain that the expansion spaces are really provided. The boards burn out and leave the spaces. If any of these spaces are carried through to the outside walls the outside boards should be removed and the spaces filled with asbestos fibre tightly driven in a few inches.

The covering of the back combustion chamber, which has given so much trouble heretofore, should be of suspended brick arches which are made by several companies. It is common to make the horizontal depth of the combustion chambers 2 feet but it is better to make it in the larger boilers at least 3 feet as it may allow the gases to change their direction of flow with lower velocity and diminished resistance.

The smoke box in the larger boilers should be deeper than has been the custom, and the width of the up-take should be wider than the width occupied by the tubes in order to give the side tubes unrestricted exit. The object of the greater depth of the smoke box is to give more space for the gases to turn and to make it more certain that the vacuum in the smoke box will be the same in all parts.

The side walls of the setting should not touch the shell by $\frac{3}{4}$ inch, and this space should be filled by asbestos rope tightly caulked in. The non-conducting covering which is afterwards applied is placed in contact with the rope and aids in securing it.

It is the tendency at present to set boilers at considerable height above the grate on the assumption that it promotes economy. This is a mistaken idea, as anyone who is familiar with Scotch boilers must know. Aside from the boiler itself the economy depends upon the perfection of the combustion, or chemically speaking, upon burning the carbon to CO_2 with no CO. The Scotch boiler is one of the most economical types. It has a small firebox volume, and small volume

beyond the firebox, and all of the surfaces within which combustion occurs are near the fire and are comparatively cool as they have water on the other side. It thus violates all of the theories which are commonly held. Scotch boilers at sea are always operated by hot air which is heated by the escaping gas in the uptake, on the Howden System. This promotes combustion.

The reason for the existence of these errors is that the impression prevails that combustion cannot occur without very high temperatures, but it occurs in Scotch boilers as perfectly as in any, not withstanding the small furnace and combustion volumes and the lowest furnace temperature of any boiler. In other words, the lowest furnace temperature that is likely to occur is sufficient to effect the desired combination of oxygen and carbon and produce high CO_2 and no CO.

A large furnace does not compel all of the oxygen to meet all of the combustible gas because there is so much space in which they can elude each other. In the Scotch boiler the space above the fuel is so small that it is impossible for these two gases to fail to come in contact and combine. In a low set horizontal return tubular boiler, for the same reason as in the Scotch, the two gases are far more likely to meet than would be the case with the high furnace. In a high furnace it is desirable to use a very high bridge wall in order to have a restricted area to compel intimate association of oxygen and carbon.

In hand fired boilers the air for combustion should be supplied by the grate, by openings in the fire door, and in controllable quantities at the bridge wall. If the two former give sufficient air the air should not be allowed to enter through the bridge wall, or if the air through the grate and bridge wall give sufficient it should not be allowed to pass through the door. In Scotch boilers air is admitted through the door, and when the Howden System is used this air is hot.

The Scotch and other boilers with round furnaces are very free from smoke, and this shows good mixture of gases. In the Scotch boiler tested by the Emergency Fleet Corporation the gas was converted to 15 per cent CO_2 in a travel of from 2 to 4 feet from the back of the bridge wall, and the combustible gas was reduced to zero. (See Bulletin 214, Department of the Interior, pp. 272–3.) In hand firing with coal the efficiency reached 80 and with oil 84.5 per cent.

Air-cooled boiler settings

There are on the market now several so-called air-cooled boiler settings which are most excellent and prolong the life of settings to

an important extent. They consist of an inner wall of fire resisting tiles on sides and back which make a wall about 8 inches thick, an air space about 8 inches wide outside of this, and an outer wall of red brick or steel plate lined with fire resisting material. In a hand fired boiler the air for combustion is supplied to these spaces by openings in the upper part of the back ends of the sides, and top of the back end, and it is drawn into the ash pit on each side through openings in the walls below the grate. In the case of stokers it is drawn through the air spaces by a fan and forced to the air boxes of the stokers. In the case of pulverized coal the hot air is blown into the pulverizer or into the burner, or both. The hot air which enters the pulverizer drys the coal to some extent and aids combustion. In this way the furnace walls are kept cool, which prolongs their lives, and the heat which is extracted from them is returned to the fire. The hot air aids combustion and shortens the flame. The air which is drawn through the setting can be previously heated by the escaping gases and yet keep the brick work sufficiently cool to prevent damage.

Grates

It is common to use shaking grates and if they are not shaken too much they are good things. Some of them have too little air space, and the air openings are often too narrow. Ample opportunity for air to pass through the grate should be given, but it should be remembered that it is easy to permit too much to pass through. This can be judged from the readings of a CO_2 indicator, which should be in every plant. With a CO_2 indicator stationary grates are as good as shaking grates, but of course require more labor by the fireman.

Mechanical stokers

Most pumping stations are too small to justify mechanical stokers. They are capable of giving economical service, but they, like ordinary grates, are capable of admitting too much or too little air, and the air cannot be controlled except by the condition of the fire. With western coal their ability to be smokeless may be sufficient justification for using them.

Pulverized coal

The most perfect means of burning coal is by pulverization and blowing it into an empty furnace. By its use a boiler can be made to

respond to demands for steam much more quickly than by other means, as when the coal supply is increased it burns instantly, and when it is reduced the effect is instantaneous. When the time arrives for stopping the fire the coal is shut off from the pulverizer and the machine is stopped. No coal is required for banking, but if the boiler is required to be started it can be more quickly done than by other methods of burning. The coke in the ash is less than by any other means of firing, and the ash requires removing only once a week or once in two weeks.

On account of the ease and quickness of adjustment of the air to the fuel, and their intimate mixture, better economy can be maintained than by any other means, and the ease of adjusting the amount of coal to the requirements prevents waste. Both the coal and air supply can be automatically regulated by the steam flow, if desired.

The air cooled boiler setting is well adapted to pulverized coal, as the hot air can be used for driving the coal through the pulverizer and thus drying it, and by blowing it into the burner, which aids combustion and shortens the flame.

Pulverization is the best means of burning inferior coal, and little if any is too poor to be burnt in this way. Coal that contains so much sulphur that it cannot be used on hand grates or stokers, can be consumed, if pulverized, without difficulty. Likewise very high volatile coal which interferes with stoker performance can be burnt with equal facility. Any kind of coal can be burnt without smoke.

Pulverized coal has passed the experimental stage and nobody should hesitate to use it on the ground that it has not. Small improvements will constantly be made as in other things. Burners need these slight improvements more than other parts.

The Scotch boiler

Various comments have already been made concerning this type of boiler, and its standing as an economical one has been shown.

This is a boiler of the internally fired type, and if made with a water leg combustion chamber has no brickwork except the bridge wall. It has from one to four circular furnaces, depending upon the size, and has been made up to 18 feet in diameter for steamships, and is frequently made 17 feet 6 inches in diameter. The maximum pressure is usually 220 pounds per square inch, although it could be made for higher pressure, and they have been made with plates 2 inches thick.

The furnaces run from the front end of the boiler to a combustion chamber in the back end which extends high enough to cover the ends of the tubes. Above the furnaces there are small tubes, 2 to 3 inches in diameter which pass to the front and where they discharge into a smokebox on top of which rests the connection to the chimney.

Waste gas superheaters or air heaters or both may be placed in the uptake, and at sea air heaters are always used, but usually in connection with forced draft. Forced draft, however, is not necessarily used.

While at sea water leg combustion chambers are always used, on land a brick lined combustion chamber is common, and on the whole, on land, is the more desirable, considering first cost and absence of stay holts. The economy is not affected by either kind of combustion chamber.

The defect of this type of boiler is that it is large for its heating surface, which can hardly be more than 3000 square feet and is expensive per square feet. As there is no brick setting the cost per horsepower compares favorably with the horizontal return tubular boiler with the setting included.

The boiler is covered with the usual kind of non-conducting material, generally 2 inches thick.

The vertical fire tube boiler

This type of boiler is used extensively in the New England states in all situations, and in sizes up to 500 h.p. This size can be built for 250 pounds pressure, and is often forced to more than 300 per cent of rating. It is not only an efficient evaporator, but it superheats the steam from 15° to 40°F. depending upon the length of tubes exposed to the steam. The steam can be still further superheated by means of the locomotive type of superheater.

A vertical tube absorbs heat throughout its circumference and is perhaps a better heat absorber than a horizontal tube. Tubes sometimes leak at their lower ends, but this can be prevented by welding them in, as is commonly done on locomotives and other boilers.

Many persons think that there is an inherent lack of economy in such boilers, the argument being that as the tubes are vertical the gases rapidly pass out and do not leave their heat behind them. This is an erroneous view. The truth is that the damper is opened enough to burn the amount of coal necessary to make the steam needed, and

as a result a certain number of cubic feet of gas pass through the tubes in a unit of time. This fixes their velocity, and they can move no faster than they would if they passed through horizontal tubes.

An important thing in connection with this type of boiler is tightness of construction of the smokebox. The smokebox should be the extended shell, or a shell tightly riveted or bolted to the boiler, and the top covers should be designed so that they will be air tight. If this is attended to, the escaping gases will be hotter than in boilers set in brickwork, and yet with superior economy. This is true of all internally fired boilers, such as the Scotch and locomotive types. Usually vertical boilers are provided with movable covers in several parts which cause the temperature of the escaping gas to be below that of the steam, on account of leakage of air through the spaces between the covers into the smoke box. All internally fired boilers with tight smoke boxes expel hotter gas than boilers set in brickwork because there is no opportunity for air to leak in and cool it. This is important where economizers are used, to say nothing of the conservation of chimney draft. Air leakage through brickwork is a source of waste. Very little of it enters where it can assist combustion.

This type of boiler requires less draft than other types because the air passes through the fuel bed at right angles to it and encounters less resistance.

Locomotive type boilers

This type of boiler is one of the best and always gives economical results. It can be made from very small to very large sizes and to carry any pressure, say up to 300 pounds.

A brick arch can be used in this boiler such as is used in locomotives. This lengthens the path of the gases, which otherwise would be very short, and enables the air which passes through the fire doors to mix with the combustible gases and produce high CO_2. If the brick arch is not used the chance of there being a good mixture of the gas and air is poor, and with the arch the locomotive type of boiler is probably the most economical of all boilers.

Water tube boilers

Something has already been said about this type of boiler. It has its place beyond the limitations of the fire tube boiler as it lends itself to large size and high pressure. It is very difficult to have the

path of the gases where they will do the most good, and if baffles are near enough together to keep the gases close to the tubes the draft loss will be great.

The water tube boiler was designed to prevent explosions at a time when they were common with fire tube boilers. The idea was that if the water was in small tubes there could not be an explosion, and if one should occur it would not be serious. Experience has shown that these expectations were not realized, and when it is considered that these boilers have headers and drums, the latter sometimes being 60 inches in diameter, this is not surprising.

There are several kinds of water tube boilers. Some have water space headers made in various ways, one at each end, connected by tubes, and by one or more drums above. These are known as horizontal water tube boilers. The tubes are always inclined, 15° being considered about right. They are sometimes highest at the back end and sometimes at the front. The headers are usually inclined so as to be at right angles to the tubes, but are sometimes vertical with inclined surfaces to meet the tubes at right angles. In such boilers the drum or drums are usually horizontal, and always should be, in order to give the maximum water surface and steam volume, and to allow the steam nozzle to be at the middle of the drum and the safety valves not far from it. A long perforated "dry pipe" should be connected with the steam nozzle running in both directions.

Another kind of water tube boiler is known as the cross-drum and consists of headers connected by inclined tubes. A single drum is used and connected to the top of the lower header, this sometimes being at the front of the boiler and sometimes at the back, although generally at the front. A horizontal row of tubes from the top of the higher header conveys the steam to the center of the drum. A baffle plate of a length somewhat greater than that of the portion of the drum entered by the tubes should be hung from the upper part of the drum in front of the tube exits, with its lower edge dipping into the water. The purpose of this baffle is to prevent the entering steam from ruffling up the water, and in marine boilers this is of importance. The steam moves slowly to each end of the drums and passes around the ends of the baffle to the general steam space, above which are the steam and safety valve nozzles.

This type of boiler furnishes dry steam as was shown by tests of boilers for the Emergency Fleet, the moisture ranging from 0.75 to 1.02 per cent when working at 152 to 282 per cent of land rating. The

drum was 42 inches in diameter, the normal water level being at the center, and the throttling calorimeter began dripping water when the water level was 10 inches above the center, or 11 inches below the top. At lower ratings the moisture was as low as 0.30 per cent. These boilers were provided with perforated dry pipes. Boilers of this type carry water better than those with longitudinal drums, because the drum is supplied with steam over its whole length instead of at one end.

The headers of water tube boilers are made of steel plates, two for each header, connected together in some manner at the edges. The inner of these plates is known as the tube plate and the other as the hand-hole plate. The tubes are expanded into the tube plate and project through about one half inch, this projection being bell shaped. The plates of the header are usually, but not always, stayed together by screwed staybolts headed over. They often have $\frac{3}{4}$ inch longitudinal holes through which the tubes can be blown, and holes that are not so used are plugged by hollow metal plugs.

The holes in the hand-hole plate are closed in various ways.

Water tube boilers with bent tubes

These boilers have bent tubes and drums but no headers. They are often called vertical water tube boilers, and have 2, 3, or 4 drums, and sometimes more. The tubes enter the drums into which they are expanded and belled. By placing a pair of these boilers in one setting, boilers of enormous size have been made. Tubes $3\frac{1}{4}$ inches in diameter are most commonly used.

The efficiency of boilers of this type depends upon the location and length of the baffles. The object is, of course, to cause the hot gases to follow the tubes. Sometimes a special pair of drums connected by tubes is added, into which the feed water is introduced, thus forming an economizer. In all of this type of boiler the feed water is introduced into the last pass which serves as an economizer to some extent. This type of boiler, if the baffles are well placed, is an efficient one.

On account of the resistance of the tubes to the flow of water, and the need of a head to cause it to flow from drum to drum the water level is very variable, and rises in the front drum when the power is increased.

Baffles

The baffles in water tube boilers are means of dividing the spaces among the tubes into passages for the circulation of the hot gases in

order that the tubes may be well swept by them and given an opportunity to absorb the heat which they contain.

In horizontal water tube boilers the baffles are sometimes parallel to the tubes and oftener approximately at right angles to them. In the former case the baffles are simpler and more durable than the others, and more likely to be gas tight in consequence of not having to fit around the tubes. They are also more easily applied and removed. It should be stated, however, that transverse baffles are now often made of concrete and poured in place thus properly fitting around the tubes. They do not crack and fall out and are much more durable than tile baffles. Longitudinal baffles cause the gases to sweep the tubes more completely than transverse baffles, and through hollow staybolts in the headers the tubes can be better cleaned by steam jets than when transverse baffles are used.

Boilers with transverse baffles cause the gases to move in transverse streams, and as air that enters through the fire doors immediately turns upward, it has little tendency to mix with the combustible gases because it and the gases pursue parallel paths.

In designing horizontal baffles the tendency is to make them too short and thus cause the gases to omit the ends of the tubes and to keep out of the corners near the baffles above. Experiment shows that the gases flow close to the ends of the baffles. Horizontal baffles should be on the lowest row of tubes or no higher than on the second row. When they are higher the tubes above the bottom have little contact with the gases, and none at all near the front ends. Thus some of the heating surface becomes useless. Similarly the highest baffle should be on top of the highest row of tubes instead of under it as it is sometimes. In the latter case the upper row is nearly, if not quite, useless.

The lowest baffle, if horizontal, should be in contact with the front header, for if not it allows the cold air which enters through the door to pass directly up in contact with the header and does not aid combustion and cools the boiler. This phenomenon always occurs in boilers with transverse baffles whether fired by hand or by stokers.

The more baffles there are in a boiler the more economical it is, but there is an advisable limit in order to avoid too great a draft loss. Many horizontally baffled boilers have only two baffles, one at the top and one at the bottom, but all such boilers, unless they are very small, should have three baffles or more depending upon the size.

In both types of water tube boilers the gases make every effort to short circuit, or in other words to avoid passing into corners or parts of the boiler where there is the least obstacle. This is not only proved by draft and temperature measurements, but can be plainly seen by providing inspection holes in the sides of the boilers. Where there is no flame sparks show the course of the gases.

Circulation in water tube boilers

Much has been written on this subject. It is important for proper circulation that the water should be freely supplied to the tubes. The water in horizontal water tube boilers is impeded by the necessity of its turning around sharp corners in entering the tubes from the headers, but it probably is able to do this so that no tubes are deficient in water supply. It is an important principle that, of all parts of a water tube boiler, the tubes themselves should have the least area for water passage, so that their entrance and exit should be unimpeded.

In the header type of boiler the most active circulation is through the lowest row of tubes and moves from the lower to the higher header. In a cross drum boiler the circulation diminishes in tubes above the lowest until near the middle where it is variable. In tubes above the middle it is in the opposite direction. In horizontal water tube boilers with longitudinal drums the return circulation may be partly or largely through the drum.

Steel casings

Boilers are frequently enclosed in steel casings, and always in marine work. This is a good thing and aids in keeping the brickwork in good condition. On land it is done to prevent air from leaking through the brickwork, but it does not accomplish it. It is found by placing observation holes in the walls that streams of air can be seen burning in the combustible gases as they enter through interstices in the brickwork. It can be inferred from this that the air enters the brickwork at the bottom of the furnace and flows through it, and between it and the casing, to all parts of the setting. When it does not encounter combustible gases, or when it enters where the temperature is too low for combustion it is a source of waste. If the steel casing were not used the brickwork would be tightly pointed on the outside and leakage prevented to some extent, but in water tube boilers it is difficult, if not impossible, to prevent excessive air leakage.

Workmanship

Good workmanship is frequently mentioned, but not so well understood. It is probable that all boiler makers understand how to do good work, but sometimes do not practice it in order to reduce the cost. It consists in part in having the rivet holes drilled with all plates and butt straps in place so that the holes will exactly match, in having the plates in contact before riveting and so close after riveting and before caulking that a steel "feeler" 0.003 inch thick cannot be inserted sufficiently far to touch the rivets. The common method of punching the holes small and reaming them afterwards should be abandoned in favor of drilling from the solid, as punching injures the material. If a boiler works is equipped with suitable drilling machines the latter method is the cheaper. If staybolts are used they should fill the holes tightly and the heads should be central. If flexible staybolts are used the sockets should be welded to the plates on the outside and not screwed in, as is common, the reason being that the taper of the screw exerts tremendous splitting pressure on the plates and as staybolts are so near together and the sockets so large the solid plate between them is inadequate to stand the stress.

Tube holes should be as small as possible consistent with passing tubes in and out, in order to prevent excessive enlargement of the tubes when expanded and beaded. If tubes seriously crack in beading they should be replaced by others.

Tube and rivet holes should be slightly chamfered on both sides of tube plates and where the heads of rivets bear.

Riveting

It has long been established that the cause of the explosions of boiler shells was lap longitudinal joints which have been abandoned for many years. A relic of the lap joint is commonly used and boiler shells will not be absolutely safe until it is abandoned. The reference is to the butt joints with the inside straps wider than the outside. Part of this joint is a lap joint with its property of causing the plate to bend back and forth with changes of pressure, just as in the lap joint but of diminished amount. Bending back and fourth causes the plate to crack, and a number of wide butt strap joints have cracked but fortunately have been discovered before they ruptured. This trouble can be prevented by making the straps of equal

widths. If there are three rows of rivets on each side of the center of the joints, the outside row having double the pitch of the inner, the joint efficiency is about 86 per cent. If a greater efficiency is required the use of four or five rows of rivets each side of the center will be necessary. This causes the pitch of the outside rows to be very wide and the use of the saw-tooth form for the outside butt strap is necessary. By this means the edge of the plate is everywhere near the rivets and effective caulking can be done. These two forms of joint are illustrated in the boiler code of the American Society of Mechanical Engineers. Such joints may have a theoretical efficiency of 94 per cent but it is best to limit it to 92 per cent.

The pounding of plates near the edges to bring them close to the plates which they join, should not be permitted, and if it should be done a "flatter" should be used against the plate to take the blows of the hammer. Usually the fitting of the plates and the closing effect of the riveter brings the plates close together so that caulking can be properly done.

Size of tubes in horizontal return tubular boilers

In some parts of the country, especially where high volatile coal is used, tubes 4 inches in diameter are used. East of this region 3½- and 3-inch tubes are used. It is better to use 3-inch tubes because more heating surface can be provided in the boiler and by their use the boiler can be smaller. It is sometimes stated that it is necessary to use large tubes because small ones fill up with soot. This is true if they are not cleaned, and an advantage of small tubes is that they compel frequent cleaning. They therefore are advantageous besides having the merit of splitting the gases into finer streams, and of placing in the boiler more heating surface. Modern tube blowers enable the tubes to be blown quickly and easily.

Good combustion prevents tubes from filling rapidly with soot.

Water glasses, gauge cocks, and feed water regulators

It is customary to equip boilers with three gauge cocks and one water glass. It is better to have two water glasses because gauge cocks are seldom used, and it is important to have two means of observing the height of the water and this is provided by having two glasses. It is also important to have short water glasses in order to prevent the water from being carried too high. Glasses 6 inches long are ample for horizontal boilers of any size.

Feed water regulators are now so frequently used that they may as well be considered unobjectionable. If of the right kind they keep the water at the correct height, but sluggish action of such devices is objectionable.

Soot blowers

Soot blowers for boiler tubes render tube blowing easy and with them there is no reason for using large tubes.

Temperature of escaping gases

It has been found, by using thermo-couples at many points in the same horizontal plane of a boiler uptake and taking simultaneous readings, that the temperatures differ greatly. In a certain case the differences were as much as 100°F. In taking temperatures it is generally thought that by placing the bulb of a thermometer in the center of the uptake the most correct results are obtained, but the readings are likely to be, and probably always are, too high. A more accurate and representative means of obtaining the temperature is to use a tube of nitrogen running through the center of the longest dimension of the uptake. This operates by expansion of the nitrogen and will probably be subjected to a fair range of temperatures. This operates upon a mechanism which is graduated to indicate the temperature and it probably remains correct indefinitely.

Tests of plates from old boilers

There have been a few tests of the plates from horizontal return tubular boilers taken from the part which is subjected to the supposed maximum temperatures. It has been assumed that the plates in such positions would have important defects, but the tests show that they are as good as new with slightly lower tensile strength, indicating that they had been slightly annealed. From this the conclusion is that the quality of steel plates in boilers subjected to heat is not affected by years of service.

Importance of keeping boilers clean

Most of the troubles in boilers are due to the accumulation of "dirt" and scale. This is likely to result in the bulging of plates, furnaces or tubes of water tube boilers, and sometimes in their rupture. It causes a considerable loss of efficiency. There are various compounds

that are used for preventing scale which are effective to a greater or less extent. The determination of which suits the case in hand can be made by a properly qualified chemist and by trial. Care should be taken not to use too much compound as it causes boilers to prime and this results in lifting the water and if the chemical passes out it causes trouble in engines, turbines, dye houses, or anything in which the steam is used. There is no kind of boiler which is not injured by dirt or scale, both in condition and performance. Other means of preventing scale are used and should have competent control.

Superheated steam

Superheated steam is steam that is subjected to heat after it leaves the boiler. The heat dries out the moisture if not excessive and then raises the temperature above that due to its pressure. The superheat may be as high as 300°F. above that due to the pressure.

Moderate superheat is obtained in vertical firetube boilers and in other types by utilizing the escaping gases. For higher degrees of superheat the hot gases are used before they have given up the greater part of their heat to the boiler. A type of superheater is the "radiant heat superheater" which occupies a part of the furnace walls and is subjected to furnace temperature. Sometimes the radiant superheater and the other type are both used in one boiler. Superheaters are used in all locomotives, and for engines and turbines for all purposes.

The effect of the use of superheated steam is to reduce the steam consumption, and therefore that of fuel, to an extent which depends upon the degree of superheat. It is a very important cause of economy.

Boiler room instruments

It is impossible for a fireman to know whether he is firing properly unless there are instruments conveniently located so that he can see them. One of the most important is a CO_2 indicator and recorder. This should be checked occasionally by an Orsat apparatus and operated to show CO as well as CO_2. It is important to so fire that CO is not present because it is a cause of great loss of efficiency if present in much quantity. The reason for this is that a pound of carbon burnt to CO yields about 4450 B.t.u., but if burnt to CO_2 it yields about 14,600 B.t.u.

In firing high CO_2 is desirable, but if it is higher than 13 per cent

with hand firing there is likely to be some CO. With other means of firing, CO_2 may be safely carried higher, but if much higher, brickwork will suffer from high temperature, unless the furnace walls are air cooled or lined with water pipes.

It is also important to have a flue gas thermometer that will indicate and record the temperature. In this case the element as before stated which is exposed to the hot gases should pass through the whole width of the uptake and thus give an approximate average indication of the temperature, as it varies greatly in different parts of the uptake. It should not be placed where it is likely to encounter air from leaks in the uptake, and every part of the flue for escaping gas should be air tight at least as far as the thermometer unit.

A draft gauge is important, and a differential gauge which shows the uptake and furnace drafts is advisable.

In addition to the above a steam flow meter for each boiler, some kind of feed water meter such as a Venturi or V-notch, and a scale for weighing the coal are advisable, and of course the latter is always installed.

If superheated steam is used a thermometer for showing the total temperature of the steam is necessary.

Steam soot blowers are very important, and where they are used the flue temperature records show what effect blowing has in improving the absorption of heat by the tubes.

PUMPING ENGINES

As with boilers, there are many types of pumping engines, and there have been many efforts to improve their economy in the use of steam, whatever power medium is used. After the Cornish engine the flywheel engine became the most economical steam engine, and its economy has improved ever since.

The Morris engine that was installed at the Lowell, Mass., Water Works about 1870 by the Southwark Foundry and Machine Co. of Philadelphia was about the first economical fly wheel pumping engine in the country. This was quickly followed by the Leavitt engine at Lynn, Mass., and this was the most economical pumping engine that had ever been built up to that time. Almost immediately two of the same type were installed at Lawrence, Mass., and other Leavitt engines were built from time to time with ever improving economies.

The Morris engine at Lowell and all of the Leavitt engines were vertical. At the present time many large horizontal pumping engines

are being built, even up to 20 million gallons capacity in 24 hours. It is hardly justifiable to build horizontal engines of capacities above 10 million gallons in 24 hours. It can only be justified by low first cost, but there are other things to be considered. The horizontal engine has more power consumed by friction than the vertical, and the repairs are heavier.

As the economy improved after 1870 the vertical engine with three steam cylinders, pumps and cranks, were introduced by Edwin Reynolds of Milwaukee, and this has remained the most economical type of steam pumping engine up to the present time. These engines are of the triple expansion type, with few exceptions.

In the effort to go to extremes in economy of steam in these engines Mr. Reynolds adopted the single beat poppet valve for the low pressure cylinder, and for the exhaust valves of the intermediate cylinder. These valves are in the cylinder heads, and when closed the heads are almost as smooth and continuous as if there were no valves. Thus the clearance volumes and surfaces are at irreducible minima, and nearly ideal for the most economical results. Moreover if the valves are tight originally they are likely to remain so indefinitely. The inlet valves open away from the cylinder and the exhaust valves into the cylinder, the piston being away from the head when this occurs.

The valves of the high pressure cylinder and the inlet valves of the intermediate cylinder are of the Corliss type, but it would be better if they, too, were of the poppet type. It would, however, be desirable to make them double beat in order to balance them for the high pressure of the steam. The clearance volume would be greater for double beat than for the single, but the advantage of their remaining tight if so originally, renders them superior to the Corliss valve. The latter valve is difficult to make tight in the first place, and as it tends to wear smaller and its seat larger it must begin to leak after some service. Gridiron valves if originally tight remain so indefinitely, but they and their seats have a great deal of surface which promotes condensation of steam.

The pumps of these engines are three in number and are under the cylinders and below the shaft. The pumps are single acting and each plunger passes through a stuffing box at the top of the pump. The stuffing box may be a source of friction on the plungers if the packing is not of the best kind and carefully adjusted. The weights of the plungers are different and are such that each with the weight of the steam piston and other parts connecting the piston and plunger

are the same in order to maintain a uniform rate of revolution of the shaft. The pump plungers are connected to the steam cross heads by four rods which straddle the shaft.

The suction and discharge valves are small and are usually placed upon so-called cages rather than directly upon the transverse plates

TABLE 1

Results of tests of certain three-crank vertical triple expansion pumping engines

	LOCATION			
	Louisville	Buffalo	Cleveland	Cleveland
	Date of Test			
	May, 1909	April, 1914	October, 1918	October, 1918
Diameters of steam cylinders, inches	30–56½–84	34–64–98	36–68–108	32–60–96
Diameter of plungers, inches	33¾	32⅝	31.63	34.75
Stroke of pistons and plungers, inches	60	66	66	66
Revolutions per minute, rated	24.019	20	20.61	21.35
Capacity in twenty-four hours, rated, million gallons	24	21	20	25
Total head of water, feet	207.93	297.7	377.2	255.4
Steam gauge pressure at engine, pounds	155.15	159.43	207.1	203.8
Superheat at engine, degrees	109.8	105.2	136	114.4
Vacuum, inches	26.88	28.00	28.26	28.43
Average power steam cylinders, I.H.P.	925.7	1,074.9*	1,417	1,170
Steam per I.H.P. per hour, pounds	9.64	9.77†	8.89	9.29
Thermal efficiency steam cyclinders, per cent	22.25		25.60	22.89
Duty per 1000 pounds steam, million foot pounds	195.02	202.63	211.0	206.2
Friction of engine, per cent	5.00		5.21	3.29

* Pump horsepower.

† Steam per pump horsepower per hour.

of the pumps. This feature for certain reasons reduces the size of the pump chambers, and the cost of production.

The bed plates usually rest upon the tops of the pump chambers and thus the amount of masonry for foundations is reduced. A result of this is to make a less congested and better lighted space around the pumps.

As this type of pumping engine has given the best results of any reciprocating engines some of them are here given (see table 1).

An excellent form of horizontal compound fly wheel pumping engine is that having the two cylinders as in a cross compound mill engine and a pump behind each. An objection is that the rear heads of both steam cylinders are pierced for the pump rods and considering this and the fact that there are distance pieces between the steam and pump cylinders it is troublesome to remove the rear heads of the former. If the pump cylinders are not rather far from the steam cylinders, the cold pump rods enter the steam cylinders and cause some condensation.

These features have caused a modification of the type, such that the steam cylinders are at one end of the engine and the pumps at the other. The crossheads, connecting rods and cranks, are between the steam and pump cylinders and one head of each steam and pump cylinder can be removed without any unusual inconvenience.

Pumps of this type with moderate steam pressures without superheat will give a duty of some 137 million foot pounds of work per 1000 pounds of dry steam consumed. This can be increased to 150 millions or more by passing the high pressure exhaust through a reheater heated by the escaping boiler gases. The moisture in this steam is not only evaporated but the steam is likely to be superheated some 50°F. by this means.

Direct acting pumps without fly wheels of various sizes up to those of 10,000,000 gallons in twenty-four hours have been popular on account of their low cost and reliability. They are usually duplex, that is to say there are two pumps complete side by side and the valves of each side are operated by the other side. The effect of the connection of the two sides through their valve gears as always built, is such that the stroke of one begins before the other ends. This to some extent keeps the flow of the water continuous and thereby diminishes the impact of the water on the system. These pumps when of much size were compound on each side, thus having two high pressure and two low pressure cylinders, and sometimes they were triple expansion, thus having six steam cylinders.

In this kind of pumping engine the steam lines of the indicator diagrams from each steam cylinder are nearly horizontal and straight and the expansion of the steam is small and comes only from the steam of one cylinder entering a larger one. The duty of such an engine would sometimes reach 60 million foot pounds per 1000 pounds of unsuperheated steam. The triple expansion type was of course more economical.

It was natural that efforts should be made to improve the type so that the steam could be cut off in the high pressure cyclinder and get true expansion as in a flywheel engine. In the direct engine as built for many years, if the steam was cut-off and expanded the pressure would fall so low that the stroke would not be completed. In the flywheel engine the stroke is completed by the inertia of the flywheel which gives out energy that is stored in the first part of the stroke. In order to make the direct acting engine capable of having the steam supply cut off at some point in the stroke of the high pressure piston it was necessary to have a mechanism attached that would imitate the flywheel in absorbing energy from the steam when it was at high pressure in the early part of the stroke and give it out at the latter part when the steam had expanded to low pressure, and thus complete the stroke. Such mechanism was developed and operated with success, and was inferior to the flywheel effect only in respect to compression at the end of the stroke, which was always lacking. The mechanism consisted for each side of the engine of a pair of oscillating cylinders with plungers acting upon water. The plungers were forced in during the first half of the stroke and the discharged water raised an accumulator weight. After the middle of the stroke the accumulator forced back the water into the oscillating cylinder the plungers of which completed the stroke of the engine. These engines were built both horizontal and vertical and compound and triple expansion, but they were not in general favor.

Another ingenious application to the duplex direct acting pump for producing the flywheel effect was known as the d'Auria engine. Between the steam and water cylinders of each half of the engine and in line with them, there is a cylinder containing a piston which circulates water through a closed pipe connecting the ends of this cylinder. The area of this piston, the diameter and length of the circulation pipe are such that the water, by its acceleration at the early part of the stroke, will absorb energy from the steam and give it out at the latter part. This enables the steam to be cut off early in the stroke, worked expansively, and the stroke to be completed. The device was effective and in one case, with steam at 152 pounds superheated 179°F., water pressure 104 pounds and 5 million gallons capacity in twenty-four hours the engine gave a duty of 140 million foot pounds and used 12.7 pounds of steam per indicated horse power per hour. The friction of the engine was 7.15 per cent. This engine is not made now, but it and the Worthington economical direct acting engine are here described as matters of interest and record.

CENTRIFUGAL PUMPS

Within a comparatively few years a great deal of study has been given to centrifugal pumps with the object of increasing their mechanical efficiency and doing away with end thrust. The simplicity of the centrifugal pump is attractive, and by these studies there has been a great advance in the mechanical efficiency, which now may be as high as 84 per cent and even more. By this is meant that the power delivered by the discharge end of the pump to the water is this percentage of the driving power. It thus becomes in mechanical efficiency a closer rival than formerly of the piston and plunger pump. In order therefore to render this pump economical it is merely necessary to drive it by an economical prime mover. The low cost of a centrifugal plant is such that the fixed charges are low, and as the attendance and a few other costs are as low as, or lower than, those of a piston and plunger pump, they are being used in greater numbers.

Centrifugal pump casings should be made in halves, the division being through the shaft center. By this means the interior can be accurately machined and carefully finished, and this in connection with an accurately machined and carefully finished impeller are necessary for high efficiency. Moreover this construction renders it possible to inspect the interior.

Centrifugal pumps are made to operate against any pressure by having a number of pumps, each succeeding and taking water from the preceding and the last delivering the water to the discharge pipe. These different pumps are called stages and the casings for each longitudinal half are usually in one casting on the same shaft.

The impellers should be of bronze and the shaft should be covered with bronze sleeves to prevent corrosion with consequent loss of efficiency.

While the efficiency of centrifugal pumps, as mentioned above, can be realized it should be remembered that there are some things still to be learned about them, the theory being still uncertain. It should also be remembered that the efficiency rapidly falls off as departures are made from the rated capacity. On this account the cost of pumping by centrifugal pumps is very variable, and more so than with piston and plunger pumps.

Means of driving centrifugal pumps

Centrifugal pumps may be driven by reciprocating steam engines, steam turbines, Diesel engines or electric motors. Of the reciprocat-

ing engines, simple or compound engines of well known counter flow types, this type being the common engine in which the steam is admitted and exhausted at the ends of the cylinders, may be used. The uniflow engine may be used with great convenience and simplicity, and with an economy equal to that of a compound or triple expansion engine.

The uniflow engine has one cylinder and is so designed that the steam is admitted at each end and exhausted in the middle. It

TABLE 2

Condensing uniflow engine

Steam consumptions per indicated horsepower per hour, at 120 revolutions per minute

		APPROXIMATE RELATIVE LOADS			
		¼	½	¾	Full
Actual powers with dry steam, and steam consumption	I.H.P.	73.01	136.53	222.45	283.26
	Pounds	12.74	12.55	13.38	14.24
Actual powers with 55° to 60° superheat, and steam consumption	I.H.P.	79.26	163.26	232.00	313.62
	Pounds	11.33	11.59	12.32	12.99
Actual powers with 107° to 112° superheat, and steam consumptions	I.H.P.	74.75	151.96	217.41	295.72
	Pounds	11.67	11.82	12.10	12.30
Actual powers with 154° to 164° superheat, and steam consumptions	I.H.P.	92.37	175.35	238.23	333.15
	Pounds	9.25	10.06	10.72	11.22

Steam pressure about 165 pounds
Vacuum 23.78 to 24.95 inches.
The vacua were very low on account of too small a condenser.

should be remembered that the economy of a steam engine is derived from small cylinder loss of heat and condensation and considerable expansion. In the counterflow engine, ignoring superheat, expansion through two or more cylinders is the means of doing this, but in the uniflow engine the method of admitting and exhausting the steam accomplishes it, especially if the cylinder heads are steam jacketed, which in counterflow engines, is of little or no advantage. The physical reasons for the economy of the uniflow engine are that the steam is not exhausted through the inlet ports and does not, therefore, carry heat away from them, and as it moves directly away from the heads instead of sweeping over them it does not carry much heat

away from them. The theory is that with a given expansion of steam in a uniflow cylinder the economy will be the same as that of a multi-expansion engine of the counterflow type with the same expansion. An important feature of the uniflow engine is that the economy with different expansions does not differ as much as in counterflow engines. In other words the efficiency curve of a uniflow engine is flatter than that of a multi-expansion engine, and this renders it advantageous for variable loads.

To illustrate the economy of a uniflow engine having a small cylinder only 23 inches by 30 inches, and the small variation in the economy with different loads, the results obtained by the writer are given in table 2. The steam used was condensed in a tight surface condenser and weighed on tested scales.

Diesel engines, which use oil as fuel directly in the cylinders, can be used advantageously in some parts of the country on account of their low fuel consumption, this being due to their high thermal efficiency. There are parts of the country, however, where the price of oil is sufficiently high and of coal sufficiently low to nullify the effect of the economy of the Diesel engine. The steam driven pump is more desirable from an economical standpoint, especially if the pumping station is already provided with boilers. Diesel engines are expensive, require a good deal of room and expensive foundations. They are complicated, and not only have a number of cylinders, but an air compressor and starting tank to contain air of high pressure. The cost of maintenance is usually high, although there are places where it appears not to be excessively so. The fixed charges are high on account of the high first cost.

In small plants gasolene engines may be advisable, but a special study of each case should be made.

Electric motors are often used to drive centrifugal pumps, the source of the power often being public service stations. In general electrically driven pumps are small, but of course there is no reason why they may not be large. A great deal of consideration should be given to the safety of the electrical supply lines and lines in duplicate are desirable, and if underground so much the better.

The question of the cost of electric current is ever arising, but no matter what the cost there are cases where electricity is not advisable from an economical standpoint. If the pumping station has a steam plant with steam pumping engines and a personnel adequate to operate it, and if it has to be operated all of the time, or if not all

the time, occasionally and at any time, it is folly to buy electricity. The cost of power is made up of the fixed charges of all kinds of the plant, the cost of fuel, supplies and labor, and if these are compared with and without purchased electricity it will be found that such electricity is not advisable. If electricity must be used it will be found, considering all of the fixed and other charges, that is should be made at the plant. In regard to the particular kind of motor to be used it is best to consult an electrical engineer.

If the head to which a centrifugal pump should work is beyond its capacity it merely whirls the water in the casing, and if it is able to pump the water against the required head and the discharge pipe valve is closed it continues to whirl the water and the pressure corresponding to the maximum head to which it will work is exerted upon the casing.

If buying a centrifugal pump for the main supply it is best to have the builder furnish an efficiency curve in order to see what is likely to occur in meeting the demands for water.

Steam turbines can be successfully used for driving centrifugal pumps, but usually with reduction gears. Such gears are unobjectionable, and have a very high efficiency so that their friction does not materially affect the general efficiency of the pump assembly. Steam turbines are more economical, when of much power, than any kind of piston engine that might be used, but their economy is dependent upon a high vacuum, say 28 inches, and the condensing apparatus is frequently not operated and maintained so that the high vacuum is realized. The uniflow engine, however, will give remarkable economy even with a vacuum as low as 23 inches, and if it is 28 inches the economy is correspondingly better.

Condensers

Of the two kinds of condensers, jet and surface, there is an important advantage in the latter which is that the steam consumption of the engine can be determined with the greatest accuracy and in short tests. It is simply necessary to weigh the condensed steam as it is discharged by the air pump, and if the engine is doing constant work the duration may be as short as one hour. The weight of the condensed steam can be determined every ten minutes, and if these weights substantially agree there is no reason for continuing the test.

On the other hand if a test is made by weighing the water pumped into the boiler the test must be eight hours or more long because the

water level in the boiler is constantly varying with the result that it cannot be said that the final water level is the same as the initial. The water surfaces in boilers are always large and a small variation in the level gives a considerable error in the quantity of water. Moreover steam for any purpose can be taken from the boiler without causing an error in the steam condensed from the main engine.

Surface condensers are made with circular, rectangular or triangular cross-sections, but the latter is generally preferred from considerations of efficiency. When a high vacuum is desired special apparatus is required for removing the ultimate air.

In writing specifications it is best to determine the size of tube desired and require all competitors to base their estimates upon it. With this and a requirement of the vacuum desired comparison of prices can be more intelligently made.

Surface condensers in dirty water districts cause some trouble, but on the whole are preferable.

Tight steam engine valves

In writing specifications of pumping or auxiliary engines, it should be required that inlet steam and exhaust valves should be made tight with a full head of steam. It should not be assumed that they will make themselves so by wear. This is preferably done in the construction shop rather than after the engine is erected in the place of use. Leaky valves are a prolific source of waste of steam and of reduction of duty. Corliss valves are now regarded as less desirable on this account than poppet valves, and every high duty engine should have the latter.

MANAGEMENT

By Charles W. Sherman[1] and John P. Wentworth[1]

The general subject of water works management as treated in the Manual appears to be handled in a rather haphazard manner. Certain items of great importance are not touched upon at all, while others to which considerable space is given are more in the nature of special problems which should be allowed comparatively little space.

It would seem as though the portion of the Manual covered by Chapters 20 to 24 inclusive, bearing the general title, "Financing and Management," would better have been divided somewhat along the following lines:

- Organization of Water Department
  - Personnel and Duties
- Water Works Accounting
  - General Principles[2]
- Sources of Revenue
  - Water Rates
  - Fire Protection Service (Treated separately in subsequent chapters)
  - Guaranties on Extensions
- Operating Expenses
  - Operation
  - Maintenance and Repairs
  - Taxes
- Fixed Charges
  - Bond Interest
  - Bond Payment or Sinking Fund
  - Depreciation (Annual)
- Funds for Construction
  - Bond Issues
  - Betterment Assessments (or equivalent)
- Valuation and Depreciation
- Public Relations

In comment upon the material contained in the Manual, the following notes are submitted.

Chapter 20 "Rates of Water Charges" includes a considerable

[1] Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

[2] See Report of Committee of N. E. W. W. A., March, 1921, p. 57.

amount of material unrelated to the general subject; certainly *requirements for water main installations*, page 447, and *taxation of water plants*, extending from page 447 to page 460, are items of expense and not of water rates. The general discussion of meter rates is excellent, but there does not seem to be any discussion of fixture rates which, although unscientific, are still extensively used and should not be ignored. There does not appear to be any discussion of the steps to be followed in determining the amount to be earned by water rates, or how, after determining the gross amount required, the rates necessary to produce such amount are to be fixed.

The discussion of "price trends" to which Chapter 21 is devoted is distinctly valuable, but is either out of place in a manual of this kind, or has been given a decidedly disproportionate amount of space. It would seem more appropriate to cover the subject in a general way by a paragraph or two under the general heading of "Valuation."

Chapter 22, Valuation of Water Works, contains three times as much material on depreciation as on valuation proper. The title of the chapter might better be, Valuation and Depreciation. The amount of space devoted to the subject of depreciation seems disproportionate, although the discussion is eminently worth while and the presentation is excellent. An appreciable part of the discussion of depreciation relates to the estimation of annual depreciation, which is an important element in the annual accounts, constituting as it does one of the fixed charges to be covered by the earnings. The remainder of the discussion relates to accrued depreciation, which is the element having to do more particularly with valuation. For clearness, both branches of the subject must be treated together, but the line of demarkation should be clearly indicated.

Chapter 23, entitled "Financial Requirements of Water Works for Providing Betterments and Extensions," devotes but little space to that subject and the material presented is fragmentary and somewhat unsatisfactory. Some material in Chapter 20 relating to this same subject is not referred to in Chapter 23. The greater part of Chapter 23 is given up to a discussion of Metropolitan Water Districts, which seems unnecessary; but if a discussion is undertaken, it would be appropriate to include some mention of consolidations of private water companies and of effect of holding companies.

Chapter 24, "Operating Practice," is made up of 13 items having little connection with one another, and does not provide any general picture of operating practice. Most of the items do relate to water

works operation; others relate to extensions, which are matters of water works construction rather than operation. It seems as though most of them should have been transferred to other chapters, although it is possible that a chapter relating to miscellaneous disconnected items is worthy of inclusion.

Chapters 25 and 26 relate to fire protection. Chapter 25 is introductory and has no real relation to water works matters. Chapter 26, although headed "Charges for Public Fire Protection Service," is really in two parts, the first relating to charges for public and the second to private fire protection service. This is one of the most satisfactory chapters in the portion of the book under discussion, and few changes other than in headings seem likely to be advantageous.

SOCIETY AFFAIRS

ROCKY MOUNTAIN SECTION

Twenty-seven members and eighty-one guests attended the second annual meeting of the Rocky Mountain Section held in Denver, February 23 and 24, and in Pueblo, 24 and 25, 1928.

During the morning and afternoon sessions of the first day, papers were presented on the following subjects: Water supply and fire protection; water waste surveys; prechlorination experience at Loveland; watershed sanitation; laboratory examinations; and, water supply progress in the Rocky Mountain region. The evening session of the 23rd included a banquet, a short business meeting, and motion pictures depicting television and transatlantic telephony, shown through the courtesy of the Mountain States Telephone & Telegraph Company and the manufacture of copper pipe, shown through the courtesy of the American Brass Company.

The morning session of the 24th was taken up with papers on Fort Collins' sewage relift station, and interesting questions relating to sewage disposal, and with discussions on well water contamination and purification, sodium aluminate as an aid in coagulation and softening and other miscellaneous water works problems.

The evening session of the 24th was held at Pueblo. Following a banquet provided by the Colorado Fuel & Iron Company, two talks were given, one describing the manufacture of cast iron pipe and the other describing the new Pueblo water softening plant of the D. & R. G. W. Railroad.

On the 25th, inspection trips were made at Pueblo to the C. F. & I. steel works and cast iron pipe foundry, and to the D. & R. G. W. railroad softening plant.

The officers elected for the coming year are: Paul E. Strouse, chairman; Chester Truman, vice chairman, and Dana E. Kepner, secretary-treasurer. D. V. Bell and Paul S. Fox were re-elected as directors.

DANA E. KEPNER,
Secretary-Treasurer.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Application of Laboratory Research to the Study of Hydraulic Problems. GEORGE H. DE THIERRY. Jour. Boston Soc. Civ. Eng., **15**: 1, 1–32, January, 1928. 52 figs. Brief summary of the scientific work done in the German hydraulic laboratories covering investigations of flood effects on bridge piers, river engineering, low water regulation of a section of the River Elbe, seepage through sand dams, dissipation of energy below weirs, Shannon River power development, model investigations of canal locks.—*J. F. Pierce.*

Paper-Mill Water Supply for Nekoosa Edwards Paper Company, Port Edwards, Wis. E. P. GLEASON and C. F. WATSON. Bull. Assoc. State Eng. Soc., **1**: 55, 1926. From Chem. Abst., **21**: 175, January 10, 1927. Water for paper making should contain practically no suspended matter and not more than 15 p.p.m. true color, 0.2 p.p.m. manganese, or 0.5 p.p.m. iron. Treatment with 3 grains per gallon of alum and forty-eight hours sedimentation rendered Four Mile Creek water, containing 60 p.p.m. color and 2.5–3.0 p.p.m. iron, suitable for use.—*R. E. Thompson.*

Sulfite Waste Liquor. G. P. GENBERG. Paper Trade J., **83**: 15, 58–60, 1926. From Chem. Abst., **21**: 175, January 10, 1927. Answers from 18 mills show that average values for sulfite waste liquor are: total solids, 11.0; ash in solids, 10.4 per cent.—*R. E. Thompson.*

Electroösmotic Processes on a Commercial Scale. KURT ILLIG. Z. angew. Chem., **39**: 1085–93, 1926. From Chem. Abst., **21**: 208, January 20, 1927. Brief historical review of development of commercial use of electroösmotic processes and detailed illustrated review of processes and apparatus for electroösmotic purification of water.—*R. E. Thompson.*

Methods of Determining Iodine in Drinking Water. W. STEFFENS. Z. angew. Chem., **39**: 1098–1100, 1926. From Chem. Abst., **21**: 293, January 20,

[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

1927. If less than 70 p.p.m. chlorides are present, 50 liters of sample are evaporated to 100 cc. Potassium permanganate is added until permanent color is obtained. Flask is cooled and 3 cc. carbon disulfide and 5 cc. sulfuric acid carefully added. The carbon disulfide is then separated and the color compared with standards. Nitric acid can be substituted for permanganate with better results because bromine will not be liberated. Small quantities of organic solvents and centrifuging give the best results for minute quantities of iodine.—*R. E. Thompson.*

Phenol Wastes and Their Treatment. H. BACH. Z. angew. Chem., **39**: 1093, 1926. From Chem. Abst., **21**: 293, January 20, 1927. Purification of phenol wastes by biological action has been accomplished with excellent results. Weaker wastes are mixed with dilution water obtained from final effluent of process and passed downward through contact beds. Air is continuously bubbled up through beds. With more concentrated wastes, dilution and seeding with domestic sewage is necessary.—*R. E. Thompson.*

Purification of Gas Works Waste Water. H. BACH. Gas u. Wasserfach, **69**: 912–5, 923–5, 947–51, 1926. From Chem. Abst., **21**: 313, January 20, 1927. Detailed discussion of possible methods for, and experimental work on, phenol removal. The bacterial method is emphasized and the "Emscher" bacterial filter described in detail.—*R. E. Thompson.*

Zeolite Method of Water Softening. C. W. STURDEVANT. J. Western Soc. Eng., **31**: 399–402, 1926. From Chem. Abst., **21**: 293, January 20, 1927. Foaming, corrosion, and caustic embrittlement have not been encountered by Southern Pacific Company. Waters high in temporary hardness, calcium and magnesium carbonates, should be treated first with lime.—*R. E. Thompson.*

Softening Water with Zeolites. C. H. NORDELL. U. S. 1,608,661, November 30. From Chem. Abst., **21**: 293, January 20, 1927. Apparatus described in which zeolitic material is used in 3 sections in which water softening and regeneration and washing of zeolitic material, respectively, take place.—*R. E. Thompson.*

Purifying Water with Base-Exchange Silicates. E. M. E. FRECHOU. Brit. 244,713, December 19, 1924. From Chem. Abst., **21**: 293, January 20, 1927. Structural features of series of filters specified.—*R. E. Thompson.*

Filter for Water. C. P. EISENHAUER. U. S. 1,609,867, December 7. From Chem. Abst., **21**: 294, January 20, 1927.—*R. E. Thompson.*

Apparatus for Softening Water with Base-Exchange Substances. O. R. SWEENEY. Brit. 244,303, March 7, 1925. From Chem. Abst., **21**: 294, January 20, 1927.—*R. E. Thompson.*

Apparatus for Softening Water by Chemical Treatment. C. P. EISENHAUER. U. S. 1,608,091, November 23, 1926. From Chem. Abst., **21**: 294, January 20, 1927.—*R. E. Thompson,*

Heating and Deaërating Water by Treatment with Steam. G. H. GIBSON, U. S. 1,607,070, November 16. From Chem. Abst., **21**: 294, January 20, 1927.—*R. E. Thompson.*

Apparatus for Purifying Water by Chemical Treatment, Light, Air, and Sedimentation. J. B. FENDER. U. S. 1,608,019, November 23. From Chem. Abst., **21**: 294, January 20, 1927.—*R. E. Thompson.*

Separating Phenol from Gas Liquor and the Like. L. W. HEFFNER and W. TIDDY. Brit. 244,774, December 16, 1924. See U. S. 1,566,795 (C.A. 20, 495). Brit. 244,775. See U. S. 1,566,796 (C.A. 20,495). From Chem. Abst., **21**: 315, January 20, 1927.—*R. E. Thompson.*

A Water-Purification Substance for Laundries. KARL BRAUNGARD. Chem.-Ztg. **50**: 712, 1926. From Chem Abst., **21**: 328, January 20, 1927. General requirements for laundry water are discussed. Patent preparation (Enter 13) consisting of soda and water glass is vigorously denounced.—*R. E. Thompson.*

Heat-Insulating Paint. P. FUCHS. Chem.-Ztg., **50**: 746, 1926. From Chem. Abst., **21**: 332, January 20, 1927. Use of bright, preferably white, paint, such as will dry to smooth shiny surface, is advocated for insulating steam pipes.—*R. E. Thompson.*

Valveless Rotating Air Pump. Apparatebau, **38**: 286–7, 1926. From Chem. Abst., **21**: 343, February 10, 1927. A type of "Sihi" pump (cf. C.A. 19, 1).—*R. E. Thompson.*

Water-Level Regulator. M. BERGER. Apparatebau, **38**: 245–7, 1926. From Chem. Abst., **21**: 343, February 10, 1927. "Direct" regulator for steam boilers described.—*R. E. Thompson.*

Practical Applications of the Earth-Current Meter. BURTON MCCOLLUM and K. H. LOGAN. Technologic Papers of the Bureau of Standards, No. 351. Electrolytic corrosion of underground structures is roughly proportional to the leakage current which leaves these structures for the earth. After several years of experimentation the Bureau of Standards has succeeded in developing an instrument for measuring this current, and the results of its use in the field indicate that it is very satisfactory and of great practical value. The instrument and accessories permit the determination of the resistivity and potential gradient of the soil adjacent to a pipe. A formula is developed for determining the rate of discharge of current by the pipe from these data. Interpretation of data is considered and results of field work are quoted to show that the earth current meter gives more reliable information regarding electrolysis conditions than can be obtained otherwise.—*A. W. Blohm.*

Electrolysis Testing. BURTON MCCOLLUM and K. H. LOGAN. Technologic Papers of the Bureau of Standards, No. 355. The 1921 Report of the American

Committee on Electrolysis pointed out several lines of investigation which needed further study, and the bureau has done considerable work on some of them. As a result of this work a new method of electrolysis testing has been developed which yields much more accurate and detailed information concerning localized electrolysis conditions than it is practicable to secure otherwise. Method consists in measuring the intensity of discharge of current from a portion of a pipe line, which factor is the one most directly related to the rate of corrosion. The older methods of determining general electrolysis conditions are first discussed and then a detailed description of the new apparatus and methods for studying local conditions is given.—*A. W. Blohm.*

Forests and Water in the Light of Scientific Investigation. RAPHAEL ZON. Forest Service, U. S. Department of Agriculture. Paper brings together impartially all the well-established facts in regard to the relation of forests to water supply. Part I shows the influence of the forest on stream flow as determined by the physical method; and Part II the results by the hydrometric method. Summary of effects of forests in conserving precipitation indicates that: hydrological rôle of forests in level countries differs from that of forests in hilly or mountainous regions; in level country forests act as drainers of the soil; in hilly and mountainous country forests are conservers of water for stream flow. They increase underground storage of water to a larger extent than do any other vegetal cover or bare surfaces. Available observations upon behavior of streams in this country and abroad have established the facts that: the total discharge of large rivers depends upon climate, precipitation and evaporation; regularity of flow of rivers and streams throughout the year depends upon the storage capacity of the watershed, which feeds stored water to the streams during the summer through underground seepage and by springs: the forest plays an important part in the storage capacity of a watershed; floods which are produced by exceptional meteorological conditions cannot be prevented by forests, but without their mitigating influence the floods are more severe and destructive. A very complete bibliography is included in this well prepared report.—*A. W. Blohm.*

A Physical Study of the Mokelumne Pipe Line. LLOYD T. JONES and WALTER S. WEEKS. University of California Publications in Engineering, 2: 9, 277, October 20, 1927. The cities lying on the east side of San Francisco Bay have formed the East Bay Municipal Utility District for the purpose of bringing water some 90 miles from the Mokelumne River to the reservoirs at Berkeley and Oakland. The aqueduct consists of about 80 miles of steel pipe and the necessary amount of cement-lined tunnel to carry the water through Berkeley hills. Considering the fact that 80 miles of steel pipe of the size contemplated, if riveted, might have a maximum permissible leakage sufficient to supply a city of more than 10,000 population, was sufficient reason to justify welding. The usual process of acetylene welding of the line began March, 1926. Due to unforseen difficulties, change to riveting was ordered in May, 1926. Acetylene welding was continued for 26,000 feet. As an aid to acetylene welds an electric metal-arc weld was placed on the inside of the girth welds. No electrically backed-up weld has broken during the construction of the line.

As a production process, it is hardly advisable. The steel pipe had an inside diameter of 65 inches, and thicknesses of $\frac{3}{8}$, $\frac{7}{16}$ and $\frac{1}{2}$ inch, in sections of 30-feet in length. Motion of the pipe line while under construction, and most of the stresses in the line are due to changes in temperature. During the time of observations some twenty breaks occurred and in every case the break was only across the top of the weld. In not a single case did the entire weld break. Fractures varied in length from one to sixteen feet, the circumference of the pipe being about seventeen and one-half feet. This publication contains an excellent treatise on: the motion of a pipe line; pipe line stresses and their measurement; two programs for laying, welding and backfilling of pipe, and ventilation in a pipe line under construction. The conclusions, briefly stated, are: resistance to movement of the pipe through the dirt was apparently of a viscous nature; all pipes should be joined together while the top and bottom are at the same temperature; group method of laying and joining pipe is logical method for pipe line of this size; distance pieces inserted at time of minimum temperature leave the line in less tension than that resulting from a continuous-laying method; maximum stress measured was approximately 12,000 pounds per square inch; electrically-backed-up welds are satisfactory except for 4000 pounds per square inch hazard due to cold-water stress; comparison of first 371 welded joints and first 371 riveted joints show 4.44 per cent of linear feet of weld broke, 4.54 per cent of linear feet of rivets removed as defective; 65 inch pipe line can be either electrically or acetylene welded without fear of breakage if information contained in this paper is heeded.—*A. W. Blohm.*

The O'Shaughnessy Dam and Reservoir. JOHN H. GREGORY, C. B. HOOVER and C. B. CORNELL. Proc. Am. Soc. Civ. Eng., **54**: 2, 405–69, February, 1928. The design and construction of a dam and reservoir built to increase the storage of raw water for Columbus, Ohio, are described. The dam is of concrete masonry, of gravity overflow type, 1750 feet long including the approaches. The masonry portion of the dam is 879 feet in length. Above the overflow section is a concrete arch bridge of 12 spans. The crest of the spillway is 64 feet above low water in the river and 84 feet above the rock foundation. The spillway capacity is 110,000 cubic feet per second, which is considerably more than the maximum flood flow. The site was selected after more than a year of preliminary surveys, studies, and investigations. It is about 16 miles north of the center of the city. The diamond drill core borings indicated that there were no sub-surface conditions seriously detrimental to its selection. Plans for various sections of the spillway are shown. 79,569 cubic yards of concrete were used, 56,139 cubic yards being 1:3:6 mixture and most of the balance being 1:2:4. An expansion joint was located under each arch of the bridge. Approaches at each end of the spillway section were built of earth embankment with a core wall in the center. The area of the water surface at elevation 845 is 1.57 square miles. The maximum depth of the reservoir is 69 feet, and the average depth, 19.8 feet. The total volume impounded is about 5,400,000,000 gallons. Detailed description of the construction is given, and the article is well illustrated. The total cost, exclusive of engineering, was $2,220,080. Work was started on the construction in June 1922 and it was completed in June, 1925.—*John R. Baylis.*

The Treatment of the Water Supply of the City of Columbus, Ohio. CHARLES P. HOOVER. Proc. Am. Soc. Civ. Eng., **54**: 2, 471–84, February, 1928. The plant is provided with facilities for softening and fitration. The design was flexible and the plant is being operated as effectively as the most recently built plants. The sudden changes in the Scioto River water necessitate constant supervision to ensure proper treatment. A chemist is kept on duty day and night. The water as it enters the plant is divided into two approximately equal parts. The lime, soda-ash, and alum necessary to soften and clarify all the water are added to one part, which is then stirred for about 10 minutes. This over-treated portion of the water joins the untreated portion at the entrance to the baffled mixing basin. The period of mixing in this basin is about one hour. Just before the clear settled and softened water leaves the settling basins, carbon dioxide gas is applied to neutralize the excess lime. It is economy to soften to about 85 parts per million. The alum used is made at the plant. The recarbonating plant consists of a gas producer, a gas burner, a boiler, a steam-driven air compressor, a combination scrubber and drier, and a diffuser.—*John R. Baylis.*

Silting of the Lake at Austin, Texas. T. U. TAYLOR. Proc. Am. Soc. Civ. Eng., **54**: 2, 569–77, February, 1928. The lake formed by the old dam across the Colorado River filled with silt to 52 per cent of its original volume in 6.75 years. The lake formed by the new dam has filled to 95.39 per cent of its volume within 13 years.—*John R. Baylis.*

Progress Report of the Committee of the Irrigation Division on Interstate Water Matters. Proc. Am. Soc. Civ. Eng., **54**: 3, 121–30, March, 1928. Interstate river controversies, if left to chance solution, lead to costly and protracted litigation. The Irrigation Division of the American Society of Civil Engineers recommends that the proper state agencies take the initiative in starting and completing such negotiations as will bring about the solution of interstate water difficulties.—*John R. Baylis.*

Report of the Committee of the Irrigation Division, on Drainage of Irrigated Lands. Proc. Am. Soc. Civ. Eng., **54**: 3, 131–52, March, 1928. This report discusses the water-holding capacities of various soils and why drainage is desirable for most irrigated soils.—*John R. Baylis.*

Report of the Committee of the Sanitary Engineering Division on Stream Pollution Matters. Proc. Am. Soc. Civ. Eng., **54**: 3, 155–6, March, 1928. Discusses briefly consideration by the committee of increased facilities for presentation, discussion, and publication of data, results of research, and papers in the field of stream pollution. The committee does not believe that the formation of a new national society is justified.—*John R. Baylis.*

Upward Pressure Under Dams: Experiments by the United States Bureau of Reclamation. JULIAN HINDS. Proc. Am. Soc. Civ. Eng., **54**: 3, 686–708, March, 1928. Uplift measurements were made on three gravity diversion dams and one gravity storage dam. Materials deposited above a dam built

on porous foundation act somewhat as a filter, partly relieving the uplift pressure and offering considerable resistance to the passage of water. When the filter surface is disturbed, as in time of flood, the uplift pressure is greater. At one dam founded on shale there was no evidence of appreciable uplift. For sandstone, the uplift pressures vary with the up-stream and down-stream water levels, roughly as a straight line from full tail-water depth at the toe to full tail-water plus one-fourth the difference between tail-water and head-water elevations at the heel. The article is well illustrated.—*John R. Baylis.*

Chemical-Electric Measurement of Water. A. BARBAGELATA. Proc. Am. Soc. Civ. Eng., **54**: 3, 789–802, March, 1928. The flow of water may be measured by introducing a concentrated salt solution of known strength at a constant rate and measuring the concentration of the dilution either by chemical titration or by electrical conductivity.

$$Q = q_c \frac{C_1 - C_2}{C_2}$$

Q is the discharge of the stream in liters per second, C_1 is the grams per liter of sodium chloride in the strong salt solution, q_c is the rate at which the salt solution is introduced in liters per second, and C_2 is the grams per liter of sodium chloride in the stream at a point sufficiently below where it is applied to insure thorough mixing. The results obtained check closely those found by current meter or bulk measurement.—*John R. Baylis.*

Precise Weir Measurements. E. W. SCHODER. *Discussion.* R. L. PARSHALL. Proc. Am. Soc. Civ. Eng., **54**: 3, 817–20, March, 1928. All parts of a moving mass of water do not advance uniformly and cross-currents are set up. When the stream is led over a weir notch, the velocity is then sufficient to produce unequal variations in motion in the approach section, causing a departure from the ideal. All known means of damping the oscillating pulse of the water fail to bring about total elimination of the rise and fall of the surface. Exactness in weir measurements is difficult to obtain.—*John R. Baylis.*

New Theory for the Centrifugal Pump. A. F. SHERZER. *Discussion.* F. T. MAVIS. Proc. Am. Soc. Civ. Eng., **54**: 3, 831–6, March, 1928. It is not to be expected that any theoretical equation can be developed for the flow of water through a pump; for the water passages of the actual pump are not perfectly smooth and frictionless and there are not an infinite number of infinitely thin impeller blades, each exerting no pressure on the water in the impeller.—*John R. Baylis.*

Baffle-Pier Experiments on Models of Pit River Dams. I. C. STEELE and R. A. MONROE. *Discussion.* Proc. Am. Soc. Civ. Eng., **54**: 3, 857–69, March, 1928. B. E. TORPEN. It cannot be expected that a single series of tests on a special phase of the subject can establish the type of treatment best suited for all sites. Results of a series of tests on a 1 to 20 scale model of the Bull Run Dam for Portland, Ore., are given. O. REED. Baffle-piers for the Miami Valley dams gave poor results. Caution must be observed in interpreting

model experiments, for slight peculiarities in the model might correspond to great irregularities in the complete structure. H .K. Fox. An arrangement for reducing the velocity of water at the end of a pipe to prevent erosion is given.—*John R. Baylis.*

The Pumping of Clay Slurry through a Four-Inch Pipe. W. B. Gregory. Proc. Louisiana Eng. Soc., 13: 6, December, 1927. The deposit in the coagulation basins of the New Orleans water purification plant, which uses the iron and lime process, was considered as source of raw material for the new cement plant of the La. Portland Cement Co. on the Industrial Canal. This would involve the pumping of about 60,000 tons per year (dry weight) to a distance of about 45,000 feet. The paper reports the results of experiments in pumping this material which varied from 11.8 to 52.0 per cent solids by weight. The slurry has some of the properties of a viscous fluid while in other ways it behaves like a very plastic solid. The critical velocity, which is the economical velocity for pumping, varies with the density of the material. Above the critical velocity, with a turbulent flow, it behaves very much like water. Below the critical velocity it is most unlike water, as the losses due to pipe friction were independent of the velocity. The apparent viscosity of the slurry at the critical velocity varied from 24 to 85 times that of water, depending on the amount of solids present.—*John H. O'Neill.*

Natural Mineral Waters and Modern Research. Oskar Baudisch and David Davidson., Arch. Int. Med., 40: 490, October, 1927. Editorial, Jour. American Medical Association, 89: 1874, November 22, 1927. Occasionally scientific research overtakes empiricism with a lucid explanation for beliefs long held without readily defensible reasons. Examples of this are the discovery of iodine in salt springs traditionally known as "goitre waters" and the discovery of radioactive properties of popular springs and baths. The investigation of Saratoga Springs by the authors shows that these waters display a catalytic activity due to ferrous iron present in special molecular arrangement and independent of dissolved or bicarbonate carbon dioxide. The principal biochemical feature of the potent iron present recalls the fact that iron is indispensable to cellular respiration. It is not inconceivable that "catalytically active" iron may have therapeutic uses even though they are still undefinable. It is noted that sojourn at the spas of today involves as a rule considerable change in the patient's regimen and in nutrition, rest, change of diet, different forms of physical therapy and probable psychological effects.—*John H. O'Neill.*

Experimental Studies of Water Purification. III. Discussion of *B. coli* Results Obtained From Primary Series of Experiments. H. W. Streeter. Public Health Reports, 42: 28, 1841, July 15, 1927. This very excellent paper deals with the *B. coli* results as obtained from certain studies at the United States Public Health Service experimental water purification plant at Cincinnati, Ohio, and with their mathematical interpretation. Summary is best presented by the author's conclusions and discussion. "(1) That the quantitative expression of the results of routine *B. coli* tests in terms of the 'most

probable numbers' yields average figures which, though more nearly representative of the true density of *B. coli* in a given water than are those based on the ordinary *B. coli* index, do not alter materially the basic relationship between the raw water and the various effluents in this respect, on which the main conclusions to be derived from the primary series of experiments depend. (2) That the indicated maximum 'most probable number' of *B. coli* in the raw water consistent with producing a chlorinated filter effluent conforming to the revised United States Treasury Department Standard approximates 9000 per 100 cc., the corresponding maximum, as expressed in terms of the Phelps index, being 6000 per 100 cc. The maximum raw water *B. coli* content consistent with producing an unchlorinated effluent meeting the same standard is indicated as being approximately 100 per 100 cc., as expressed in terms both of the *B. coli* index and of the 'most probable number.' (3) That the inclusion of tests of filter effluents, both unchlorinated and chlorinated, in portions of samples less in volume than 10 cubic centimeters (a) gives decidedly higher average indicated densities of *B. coli* in these effluents, and (b) yields results which appear to be more consistent with those obtained from geometric-series dilutions, than does the exclusion of such tests. (4) That for bacterial densities falling within the range of the ordinary plate count, the acid-colony count on the Ayers-Rupp medium gives results which are of the same general order of magnitude numerically as the 'most probable numbers' of *B. coli*, as determined by the fermentation-tube test.—Perhaps the most significant of the foregoing conclusions is that which is concerned with the 'most probable numbers' of *B. coli*. In spite of the fact that the basic relationships involved in these studies are altered to a very small extent by conversion of the *B. coli* data to these terms, striking experimental evidence is found from the comparison with the Ayers-Rupp counts that the density of *B. coli*, as given by the 'most probable numbers,' approaches more nearly the expected order of magnitude than when expressed in terms of the ordinary *B. coli* index. The correspondence between these two quantities throughout a large portion of the entire range of their variation was consistently too close to be regarded as fortuitous. In routine filtration plant control work the *B. coli* index should yield average results, when converted to terms of bacterial efficiency, which are fairly consistent with those given by the corresponding 'most probable numbers' of *B. coli*. In such work, however, as well as in the research field, it is often of primary importance to determine, from a given series of tests, the closest possible approximation to the actual density of *B. coli* in the raw water or effluent. This object can be accomplished with far more precision and with little, if any, greater effort, by converting the result of each individual test to terms of the 'most probable numbers' of *B. coli*. The figures thus obtained may be averaged, or treated statistically in any other manner, like the *B. coli* index or the ordinary plate count of bacteria. Although the *B. coli* index doubtless will continue to be used generally in routine plant control work for some time to come, the improved method of enumeration represented by the 'most probable numbers' of *B. coli* will gain rapidly in favor with a wider understanding of its greater precision and relative simplicity, when reduced to a tabular system of results as obtained from individual tests."—*R. E. Noble.*

Coöperative Rural Health Work of the U. S. Public Health Service in the Fiscal Year 1927. L. L. LUMSDEN. Public Health Reports, **42**: 42, 2545, October 21, 1927. That part of the report dealing with Water Supplies is summarized: "The protection and improvement of the water supplies has occupied a considerable amount of the time of the sanitary officers. They have given attention to both municipal and individual supplies. As a routine procedure they make frequent inspection of the municipal and community supplies and collect samples for examination." 1018 places have been provided with a safe water supply. Owing to drouth the town of Pulaski, Virginia, supplemented its regular reservoir water supply by pumping water from the South Fork of Peak Creek direct into the mains. In this connection a chloride of lime treatment plant was operated under supervision of the sanitary officer. No outbreaks of typhoid or dysentery occurred, indicating the effectiveness of this sterilization process. "Three water-main extension projects were completed in Roanoke County, Virginia. As a result, 318 water connections were made and this number of homes have been provided with pure drinking water. Samples collected from the water supply for South Salem, Virginia, showed that it was polluted. The sanitary officer immediately installed a chlorinated-lime treatment plant, and subsequent samples have been found excellent on bacteriological examination. In October a bond issue for $75,000 was passed by voters of Farmville, in Prince Edward County, for improvements to the present water system. These include a wash-water tank, a new intake line, a new standpipe, and three-quarters of a mile of 10-inch mains. The filters at the Farmville water plant were recently overhauled and rebuilt under the direction of the sanitary officer." At Hampden-Sidney, Virginia, the chlorinator was repaired. The filter was cleaned several times during the year. "A bond issue of $70,000 was carried in Martinsville, in Henry County, to enlarge the present water system. The new source of supply is Beaver Creek, about 1½ miles north of town. This has necessitated the laying of several miles of new mains, the building of additional filters, and the installation of a large pump for forcing the water into the standpipe. The commercial concerns selling bottled spring water have not been neglected. Inspections are made regularly to collect samples and to see that the bottles are properly washed and sterilized. These plants distribute many thousands of gallons of water, some of it being shipped to distant communities."—*R. E. Noble.*

Court Decisions Relating to Public Health. Public Health Reports, **42**: 33, 2105, August 19, 1927. "Referendum not allowable in case of an ordinance declared to be an emergency measure and in the interest of public health." (Ohio Supreme Court; State ex rel, Smith *v.* City of Fremont, 157 N. E. 318; decided May 11, 1927.) Public Health Reports, **42**: 38, 2346, September 23, 1927. "Creation of water district and assessments against property therein upheld."—(Kentucky Court of Appeals; Ryan *v.* Commissioners of Water District No. 1 of Kenton County et al., 295 S. W. 1023; decided June 24, 1927). Public Health Reports, **42**: 41, 2508. October 14, 1927. "Compensation granted under workmen's compensation act for death from typhoid fever."—(California First District Court of Appeal, Division 1; Fidelity and Casualty

Co. of New York *v.* Industrial Accident Commission of California et al., 258 P. 698; decided July 20, 1927.)—*R. E. Noble.*

The Purification of Natural Oysters in Natural Waters. C. KRUMWIEDE and W. H. PARK and others, American Journal of Public Health, **18**: 1, January, 1928. Oysters were contaminated by placing them in cold sea water to which feces containing B. typhosus had been added. This organism could not be isolated from the shells after 24 hours, or from the liquor after some period between the 10 and 17 days. Pooled gills, however, were still positive for B. typhosus on the 51st day. Oysters were then exposed to contaminated sea water at temperatures insuring active "drinking." B. typhosus was isolated from oysters after 9 to 11 days, but not after 16 to 24 days, and from the water after 19 to 24 days. It was concluded that infected oysters free themselves of pollution in 3 weeks when allowed to drink in unpolluted sea water.—*C. R. Cox.*

Relief Measures During and Following the Mississippi Valley Flood. J. H. O'NEILL. American Journal of Public Health, **18**: 2, February, 1928. Outlines the administrative machinery organized to offer relief to those living in flood area. Most of relief camps were located where water from municipal supplies was available, although water was hauled in tank cars from distant points at certain places, or local supplies were disinfected with chloride of lime under direction of public health officials. Fly-proof pit latrines were used in most camps which had to be carefully policed. Water works were protected by special levees and extra pumps were installed to remove leakage. Many supplies were chlorinated with equipment loaned by the manufacturers. Full-time county health units were established in 87 counties, following the receding of the flood waters, through coöperation of counties, the states, the Federal government, and the Rockefeller Foundation.—*C. R. Cox.*

ABSTRACTS, SUB-COMMITTEE NO. 9

JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES

Water—and the Corrosion of a Boiler Plant. Power House (Toronto), **22**: 5, March 5, 1928, pp. 24–25. Brief article treats of chemistry of corrosion.

Fouling of Boiler Surfaces Exposed to Radiant Heat (Verschmutzung der bestrahlten Heizflaeche von Wasserrohrkesseln). PETERS. Waerme, **50**: 45, November 14, 1927, pp. 773–775, 4 figs. Refers to ROSIN's heat content-temperature diagram showing relation between heat content of furnace or flue gases of stated composition and corresponding temperature of combustion; front row of water tubes should be kept clean; recommends that steam blower be situated above inner end of ignition arch, and water cooled when not in use for steam. Brief translated abstract in Eng. and Boiler House Rev., **41**: 8, February, 1928, p. 386.

Priming and Impurities in Feed Water. A. W. EWELL. Power, **67**: 9, February 28, 1928, pp. 370–373, 1 fig. Experimental results indicate that priming is

increased by presence of acids including hydrolyzed salts, non-dissociated substances such as sugar, slightly dissociated salts such as lead acetate, and insoluble oils; increase in priming is attributed principally to increase in density and viscosity; priming is decreased by insoluble solid particles and by highly dissociated salts.

Lime and Soda Treatment of Feed Water. E. M. PARTRIDGE. Power, **67**: 12, March 20, 1928, pp. 507–509. Results obtained by lime-soda softeners on division of Mid-Western railway; accompanying tables of analyses support statement that water may be actually more corrosive in character by partial softening with lime and soda and that lime-soda softening does not insure formation of soft sludge in boiler unless treatment be complete.

Some Notes on Water Softeners and Water Softening. W. L. ASHMAN. Gas Engr. (London), **44**: 622, February, 1928, pp. 42, 1 fig. Chief scale-forming impurities are carbonate of lime, carbonate of magnesia, sulphate of lime and silica; hardness is divided into two types referred to as "temporary" and "permanent" hardness; feed water treatments; French process consists in adding ammonium hydrate to water, in type of softener plant; lime-soda process; filtration before softening. See also Gas Jl. (London), **181**: 3378, February, 1928, pp. 398–399. Paper read before West. Junior Gas Assn.

Feed Water and Boiler Efficiency. W. G. LEWIS and G. S. IRVING. Eng. and Boiler House Rev., **41**: 8, February, 1928, pp. 378 and 380. Review of 64-page publication issued by Feed Water Specialists Co. dealing with problem of water treatment in simple yet fundamental manner and containing rather wide range of matter which is essential to steam engineer, but not always readily available when required; definition of colloidal condition; electrical conditions of colloids; water softeners.

Feed-Water Treatment Retards Boiler-Plate Embrittlement. S. W. PARR and F. G. STRAUB. Power, **67**: 10, March 6, 1928, pp. 444–445. Sodium phosphate and tannate in relatively small quantities have been found by authors to retard embrittling action of caustic soda; their use, it is thought, will avoid some of present difficulties of maintaining correct sulphate ratio; treatment of feedwater with those reagents is, however, still in laboratory stage of development.

The Importance of Water Purification in Central Steam Plants (L'importance de l'épuration de l'eau dans les centrales à vapeur modernes). Génie Civil (Paris), **92**: 9, March 3, 1928, pp. 214–215. Study of sedimentation and softening of boiler feedwater with various chemicals.

Progress Report on Feedwater Treatment for 1925-27 (Bericht ueber die Fortschritte in der Aufbereitung des Speisewassers in den Jahren 1925-27). K. HOFER. Chemiker-Zeitung (Fortschrittsberichte), **52**: 11, February 8, 1928, pp. 10–18. Review of American and European literature detailing advances in filtration, purification, softening, neutralization, etc. of industrial

water supplies by mechanical, thermal, and electrochemical methods; removal of boiler scale; international bibliography of 254 references.

The Elimination of Oil from Boiler Feed Water. C. N. RIDLEY. Eng. and Boiler House Rev., **41**: 8, February, 1928, pp. 374–376 and 378, 4 figs. When exhaust steam from engines is condensed, and condensate mixed with make-up water for boiler feed, oil used in lubrication is invariably carried over with condensate into feedwater and enters boiler; separation of oil from exhaust steam; filtration; chemical and electrical elimination.

Operation and Control of Rapid Sand Filters. S. T. POWELL. Mun. News, **7**: 2, February, 1928, pp. 52–54. General discussion of difficulties encountered and means of overcoming them; determining proper dose of coagulant; filter bed; air bound filters; controllers, gages, and similar appurtenances; analytical tests. Paper presented before Maryland Water and Sewage Plant Operators.

Report of the Committee on Water Service. Ry. Age, **84**: 9B, March 7, 1928, pp. 560–D62–D68. Drinking-water conditions during Mississippi flood; pitting and corrosion of boiler tubes and sheets; sodium alumnate as aid to water softening; carbonate and sulphate waters; influence on operation and maintenance of boilers and cost of purification; hydrants for coach yards and general service and methods for supplying water to coaches; disposal of sludge at water-softening plants; spacing of water stations in connection with increasing capacity of engine tenders. Abstract of report to Amer. Ry. Eng. Assn.

Operating Experience with High Pressure and High Temperature Steam. G. A. ORROK. Power Plant Eng., **32**: 5, March 1, 1928, 320–322, 1 fig. Concludes that there appear to be no serious difficulties in operation of plants using pressures ranging up to at least 2000 pounds per square inch; four years' experience in continuous operation of superheaters raising steam temperatures to 850 degrees Fahrenheit with ordinary steel superheater tubes has proved such operation commercial.

Corrosion in Steam Heating Systems. F. N. SPELLER. Domestic Eng. (Chicago), **122**: 10, March 10, 1928, pp. 23–24 and 61–62, 4 figs. Corrosion of steam-heating systems is associated mainly with certain types of boiler feedwater; three essential factors in corrosion, moisture, oxygen, and carbon dioxide.

Utilization of Waste Heat for Water Distillation and Hot-Water Heating (Abhitzeverwertung zur Destillatbereitung und nachgeschalteter Fernheizung). H. BALCKE. Gesundheits-Ingenieur, **51**: 5, February 4, 1928, pp. 73–78, 6 figs. Description of experimental installation by firm of Hugo Szamatolski of Berlin for distillation of feedwater with hot exhaust and flue gases, hot waste water of distillation plant to be piped to distant point there to be utilized for heating of buildings; detailed studies of best thermal conditions for distillation plant. (To be concluded.)

Technic and Significance of the Biochemical Oxygen Demand Determination. F. W. MOHLMAN, G. P. EDWARDS and G. SWOPE. Indus. and Eng. Chem., 20: 3, March, 1928, pp. 242–246, 6 figs. During the past 15 years much of scientific work of laboratories of Sanitary District of Chicago has been based on biochemical-oxygen demand determination; importance of B. O. D. determination as fundamental basis for past, present, and future oxygen requirements of District has stimulated continuous research on technic of method and interpretation of results; rates of B. O. D., Illinois River; significance of B. O. D. in sewage treatment.

Faults in Filter Plant Operation. J. L. BARRON. Can. Engr., (Toronto), 54: 10, March 6, 1928, pp. 282–284. Well-trained employees and up-to-date equipment necessary for efficient operation; coördination of flow to meet varying demand; cleaning settling basins and washing filters; control of chemical feed; adequate daily tests; as basis for all operating records, most essential thing is to know rate of flow and total output per 24 hours. Reprint from Water Works.

Filter Plant Troubles Traced More Often to Faulty Design Than to Poor Operation. C. A. BROWN. Hydraulic Eng., 4: 2, February, 1928, pp. 89 and 102–104. Ideal plant presupposes perfect design and perfect operation, latter depending upon skill of operators; introduction to settling basins; introduction to filters: few filters have properly designed filter bottoms. (To be continued.)

New Filtration Plant at Waukegan, Ill., Designed on Duplex Plan. Water Works, 67: 3, March, 1928, pp. 97–102, 5 figs. Duplicate plant; pumping equipment; new type aërators; sedimentation basins; filters; chlorination; handling chemicals; laboratory.

Returned Sludge in Water Purification. A. W. BULL. Water Works, 67: 3, March, 1928, p. 112. Reducing supersaturation, or lack of chemical reaction; sludge which may be obtained from coagulation basins is suitable material for this purpose; brief summary of data obtained on this point at Columbus, O., and at Pittsburgh, Pa.

Treatment of the Water Supply of the City of Columbus, O. C. P. HOOVER. Water Works, 67: 3, March, 1928, pp. 117–120, 2 figs. Operation and new features of works; character of raw water changes suddenly; process used in treatment of water supply; application of chemicals to water; limitations of lime soda-ash process of softening; recarbonation plant. Paper read before Am. Soc. Civ. Engrs.

NEW BOOKS

Hydrology of the Great Lakes. ROBERT E. HORTON in collaboration with C. E. GRUNSKY. **Report of the Engineering Board of Review of the Sanitary District of Chicago on the Lake Lowering Controversies and a Program of**

Remedial Measures. Part III, Appendix II. Chicago: The Sanitary District of Chicago, 6 North Michigan Ave. Paper; 6 by 9 inches; 432 pp. Reviewed in Eng. News-Rec., **99**: 967, December 15, 1927.—*R. E. Thompson.*

Water Channels. GEORGE HIGGINS. London: Crosby, Lockwood and Son. Cloth; 9 by 11 inches; 108 pp. 21s. net in England. Reviewed in Eng. News-Rec., **99**: 970, December 15, 1927.—*R. E. Thompson.*

Water Purification Plants and Their Operation. M. F. STEIN. 3rd ed. revised and enlarged. New York: J. Wiley & Sons, Inc. London: Chapman & Hall, Ltd. 316 pp. 15s. Chem. Abst., **20**: 3526, November 10, 1926.—*R. E. Thompson.*

Steam and Gas Turbines. A. STODOLA. Translated by LOUIS C. LOEWENSTEIN. New York and London: McGraw-Hill Book Co. Inc. Cloth; 7 x 11 in.; 1356 pp. $15. Reviewed in Eng. News-Rec., **99**: 644, October 20, 1927.—*R. E. Thompson.*

Stream Gaging. WM. ANDREW LIDDELL. New York and London: McGraw-Hill Book Co. Inc. Cloth; 6 x 9 in.; 238 pp. $3. Reviewed in Eng. News-Rec., **99**: 644–6, October 20, 1927.—*R. E. Thompson.*

The Mathematics of Engineering. RALPH E. ROOT. Baltimore: The Williams and Wilkins Co. Cloth; 6 x 9 in.; 540 pp. $7.50. Reviewed in Eng. News-Rec., **99**: 807, November 17, 1927.—*R. E. Thompson.*

Methods and Plant for Excavation and Embankment. CHAS. H. PAUL and CHAS. S. BENNETT. New York and London; McGraw-Hill Book Co. Inc. Cloth; 6 x 9 in.; 328 pp. $4. Reviewed in Eng. News-Rec., **99**: 807, November 17, 1927.—*R. E. Thompson.*

The Essen Number. Report of the convention of the Association for Water, Soil and Air Hygiene held in Essen in June, 1927. Published by and obtainable through the Landesanstalt für Wasser-, Boden- und Lufthygiene, Berlin-Dahlem, Ehrenbergstr. 38–42. 518 pages, 288 illustrations and tables. Price 12 R.M. This volume contains the proceedings of the twenty-fifth annual convention of the Association for Water, Soil and Air Hygiene held in Essen in June, 1927 (first convention outside the city of Berlin). The location of Essen in the Ruhr Valley in the heart of a thickly populated industrial section offered exceptional attractions for a convention of sanitarians.

At the same time as the convention there was an exposition ("Achema") of chemical apparatus held in Essen under the auspices of the Division for Water Chemistry of the Association of German Chemists (Verein Deutscher Chemiker). Part 9, pages 439–494, of the volume is given over to a description, profusely illustrated, of the apparatus exhibited at this exposition.

The papers covered the entire field of sanitary science from the engineering phases of water supply and waste treatment, the effects of air pollution on human population and vegetation, to the disinfection of clothing and the

control of vermin. The following is a list of the papers presented at this convention:

Water and Sewage in the Rhine-Westfalian Industrial Area, especially, with Reference to the Emscher- and Lippe Association, by H. Helbig; Sewage Treatment Works of the Emscher Association, by M. Prüss; The Disposal of Settled Sludge from a Chemical Standpoint, by H. Bach; The Work of Ruhrverband, by Dr. K. Imhoff; River Clarification and Power Installation at Hengstey, by O. Spetzler; Biological and Chemical Sewage Purification with the Aid of Air, by Dr. F. Sierp; The Left Lower Rhine Drainage Board in Moers Niederrhein, by K. Fehring; The Ruhr Valley Reservoirs, the Möhne and Sorpe Reservoirs, by E. Link; The Water Supply of the Ruhr Coal District from the Hygienic Standpoint, by H. Bruns; The Water Supply of the City of Essen, by B. Nerreter; Permutit Water Purification with a Special Reference to the Circulatory Regeneration System of Hufschmidt, by K. Hofer; Air Hygiene, by E. Wernicke; Vegetation and Poisonous Gas, especially Sulfur Dioxide, by E. Tiegs; Chemical Questions of Air Hygiene, by W. Liesegang; Air and Dust Investigation of the Rhine-Westfalian Industrial Area, by H. Reisener; Air Pollution and its Prevention, by L. Diesfeld; Question of Health Hazard of Factory Air, by F. Müller-Voigt; Communal Hygiene Questions in the Field of Vermin Control, by J. Wilhelmi; and Description of Apparatus Exhibited at the Chemical Exposition ("Achema"), by H. Bach.

The subjects are all clearly and authoritatively treated, and profusely illustrated. The volume furnishes an exceedingly valuable summary of current practice in the field of sanitation. The questions are naturally discussed from the standpoint of applications to German conditions, but references are frequently made to recent progress in other countries. Of the 350 delegates to this convention a considerable number came from foreign countries.—*A. M. Buswell.*